FDL-TDR-64-109

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
AEROPHYSICS LABORATORY

Technical Report 95

A STUDY OF TWIST AND CAMBER ON WINGS IN SUPERSONIC FLOW

Flight Dynamics Laboratory
Research and Technology Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

November 1964

(Prepared under Contract No. AF 33(657)-8898 by the Aerophysics Laboratory of the Massachusetts Institute of Technology, Cambridge, Mass; Frank H. Durgin, author)

NOTICES

(5) Aerophysics Lab, Mass. Inst. of Tech., Cambridge.

(18) (19)
FDL-TDR-64-109

(6) A STUDY OF TWIST AND CAMBER ON WINGS
IN SUPERSONIC FLOW.

~~TECHNICAL DOCUMENTARY REPORT NO. FDL-TDR-64-~~109
~~November 1964~~

(9) Final rept.,

Flight Dynamics Laboratory
Research and Technology Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

(16) (17)
Proj[redacted] 648D, Task [redacted] 905603

(14) Rept no. TR-15

Sup~~ersonic~~ ~~Transport Research Program~~
~~Sponsored By~~ The
Federal ~~Aviation~~ Agency

(15)
[redacted] Contract [redacted] AF 33(657)-8898 [redacted]

(10) by
Frank H. Durgin, [redacted]

FOREWORD

This is the final report by the Aerophysics Laboratory of the Massachusetts Institute of Technology under Air Force Contract AF 33(657)-8898 on "A Study of Twist and Camber on Wings in Supersonic Flow". This work was sponsored by the Federal Aviation Agency and technical support was given by both the Air Force Research and Technology division and the National Aeronautics and Space Agency's Langley Research Center. Mr. Joseph Nenni, Mr. Albert Murn and Mr. Edwin Dow acted as technical monitors for the Air Force. Mr. F. Edward McLean was technical monitor for the National Aeronautics and Space Agency.

The author wishes to express his appreciation to Miss Beverly J. Beane, who directed all of the analytical work leading to the design of the optimized wings. Much of this report, including most of the conclusions, is direct quotation from her notes and memoranda and is used with her permission. She also was of great help in reviewing the report.

The valuable technical assistance given by Dr. Eugene Covert and Dr. Leon Schindel is also gratefully acknowledged.

Finally, the program could not have been completed without the valuable help of Mr. Roy Krupp and Mrs. Edith Sandy who carried out nearly all the computations.

Mr. Krupp's brief description of the numerical analysis techniques employed by him is included as Appendix II of this report.

ABSTRACT

The object of this program was to study both theoretically and experimentally methods for designing the twist and camber of wing planforms to yield high lift-drag ratios at supersonic speeds. Calculations based on linear supersonic wing theory were made to determine the effects of various types of load distributions on the drag due to lift and on the wing shape. In particular, only solutions with smooth finite pressure distributions and finite perturbation velocities, leading to easily built wing shapes, were accepted. It was hoped, by imposing such constraints, to avoid the high drag losses due to shock waves, flow separation and the formation of detached vortices.

The calculation procedure was used to design versions of arrow and double delta planforms warped to obtain improved drag due to lift at Mach number 3. Both flat and warped versions of each planform were tested and both force and pressure data were obtained on all the wings. No appreciable improvements in drag due to lift were obtained for the warped versions of the wings with respect to the flat ones. It is believed that if more severe restrictions were put on the maximum pressure coefficients (both positive and negative), as well as on the permissible pressure gradients, significant improvements in drag due to lift could have been obtained.

This technical documentary report has been reviewed and is approved.

Philip P Antonatos

P. P. ANTONATOS
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LIST OF SYMBOLS

a_n	coefficient in loading series of Grant
b	wing semi-span
c	local wing chord
c	small arbitrary constant used in loading series
c_0	wing root chord
$\bar{c}$	parameter in loading series for double delta wing
$C_d = d/q\,c$	local drag coefficient
$C_D = D/Sq$	drag coefficient
$C_{D_0} = D_0/Sq$	zero lift drag coefficient
$C_\ell = \ell/Sq$	local lift coefficient
$C_\lambda = M_r/b\,Sq$	total rolling moment coefficient
$C_L = L/Sq$	total lift coefficient
$C_m = M_p/S\,c_0\,q$	pitching moment coefficient
$C_p = p-p_\infty/q$	pressure coefficient
$\bar{C}_p$	average pressure coefficient over chord
ΔC_p	$C_{pb} - C_{pt}$
$\Delta\Delta C_p$	$(C_{pb} - C_{pt})_{\alpha = 1°} - (C_{pb} - C_{pt})_{\alpha = 0°}$ or similarly for $-1°$
C_p^t	approximate theoretical pressure coefficient due to thickness
$C_x = F_x/Sq$	axial force coefficient
$C_z = F_z/Sq$	normal force coefficient
d	local drag per unit span
D	total drag
$F(\eta)$	function in loading series for double delta planform (see Fig. 15b)

$k_{1,2}$	constants in Busemann formula
K	$[(\gamma + 1) M_\infty^4 - 4\beta_\infty^2]/2\beta_\infty^3$ constant used to correct loading to second order
ℓ_0	overall length of wing measured along the x axis
ℓ or $\ell(x,y)$	local wing loading
L	lift
m	cutout portion of clipped arrow wing (see Fig. 5)
m_1	$\beta \tan \varepsilon_1$
M	Mach number
M_p	pitching moment
M_r	rolling moment about wing root
N	number of terms in loading series
p	local pressure
Δp	$p - p_\infty$
P_0	wind tunnel stagnation pressure
q	dynamic pressure
r_{cp}	radius of wing center of pressure from balance axis
R	Reynolds number based on root chord length
S	wing area
u	perturbation velocity parallel to free stream velocity
U_∞	free stream velocity
w(x,y)	local upwash
x	distance along x axis measured from wing nose or leading edge

x_{cp}	distance from balance axis to center of pressure along x axis
x_0	distance from wing nose to the change in sweep (double delta only) along the x axis
$\overline{x}$	x/ℓ_0 - normalized x measured from wing nose
$\overline{x}_0$	x_0/ℓ_0 - normalized x_0 measured from wing nose
x/c	x normalized at local spanwise station measured from leading edge
y	distance from wing root along y axis
y_{cp}	position of center of pressure from wing root
y_0	distance of the change in sweep angle (wing crank) of the double delta wing from the wing root
$\overline{y}$	$y/\ell_0 \tan \varepsilon_1$, or $y/\ell_0 \tan \varepsilon$ normalized y
$\overline{y}_0$	$y_0/\ell_0 \tan \varepsilon_1$, normalized y_0
z	distance of wing center line from x,y plane
α	angle of attack of the wing with respect to the x,y plane
α_c	angle of attack $\alpha_c = 0$ at $C_L = 0$
α_{cp}	angle along which r_{cp} is measured for warped wings
β	$\sqrt{M^2 - 1}$
δ	local slope of the wing surface due to thickness distribution
ε	complement of sweep angle of arrow wing
ε_0	$\tan^{-1} b/\ell_0$ for double delta wing
$\varepsilon_1, \varepsilon_2$	complement of sweep angles of double delta wing (see Fig. 1)
η	$\beta(y - y_0)/(x - x_0)$
λ	small arbitrary constant

LIST OF SYMBOLS (Concluded)

Λ	wing sweep angle
μ	parameter defining the wing trailing edge sweep
μ_B	parameter defining the wing trailing edge sweep for a wing with a cut off tip
σ	complement of the trailing edge sweep angle
ϕ_x	perturbation velocity
ω	$(\mu \ell_0/\beta b)$

Subscripts

b	bottom side of wing
n	digit numbering term in loading series
t	top side of wing
∞	free stream condition

CHAPTER I

INTRODUCTION

A. GENERAL COMMENTS

Flying efficiently has always been a goal of the builders of airplanes, but for the supersonic transport it is a must, because this airplane must compete with the present subsonic jets and also have long range. Long range flights are the only ones where the extra speed is of any great advantage. Examination of the classical Breguet range equation shows that for a fixed ratio of the airplane's weight full of fuel to that empty of it, the range of an airplane is directly proportional to the lift-drag ratio assuming constant speed and specific fuel consumption. Or looking at it another way, if the range is fixed, any improvement in lift-drag ratio will allow the airplane to carry more passengers and less fuel, so that the fuel used per passenger mile will be less assuming the other variables are fixed. Thus, any improvement in lift-drag ratio will improve the airplane's over all efficiency.

Since the lift of an airplane must be equal to its weight during cruise, to improve the lift-drag a way must be found of reducing the drag.

The drag of a supersonic airplane is made up of several parts:

1. drag due to skin friction
2. drag due to displaced volume (supersonic flight only)
3. drag due to aerodynamic interference between various parts of the airplane (including drag due to trim)
4. drag due to lift

Parts 2, 3 and 4 are closely related in that for a complete airplane they must be treated together but it is the drag due to lift with which this report is concerned. However, only the wing alone will be considered, because it is a logical starting point and has proved to be sufficiently difficult that, despite attempts to develop a design method, no clearly successful one has evolved.

The drag of a wing may be written as follows:

$$D = C_D S q = (C_{D_0} + \frac{dC_D}{d\,C_L^2} C_L^2) S q \qquad (1)$$

where

C_{D_0} is the zero-lift drag coefficient and includes the

Manuscript released by author November, 1964 for publication as an ASD Technical Documentary Report.

drag due to skin friction and volume, and

$$\frac{dC_D}{dC_L^2} C_L^2 \text{ is the drag due to lift.}$$

(There is no interference drag as we are only considering a wing.) Normally one thinks of the lift as varying linearly with the angle of attack of the wing. For a rubber wing cambered to minimize $\left(\frac{dC_D}{dC_L^2}\right)$, if we consider the amplitude of camber as varying linearly with the lift, then the above equation is still valid, and in the usual way

$$\left(\frac{L}{D}\right)_{max} = \left[4\, C_{D_0} \frac{dC_D}{dC_L^2}\right]^{-1/2} \qquad (2)$$

and

$$C_{L(\text{for max } \frac{L}{D})} = \sqrt{\frac{C_{D_0}}{dC_D/dC_L^2}} \qquad (3)$$

In this report an effort is made at reducing dC_D/dC_L^2 to improve the lift-drag ratio.

B. METHODS OF DETERMINING OPTIMUM DRAG DUE TO LIFT FOR WINGS

The drag due to lift is calculated by an area integral over the product of local lift and local downwash, which is itself determined by the lift distribution. Hence, minimum drag is obtained when the total lift is distributed in such a way that this integral is a minimum.

Analyses are generally restricted to linearized supersonic wing theory. Linear theory is believed to provide an adequate solution of the optimum load distribution problem for the reason that the minimum of the drag is almost certainly not a sharp minimum, but there exist many smooth shapes near the optimum which have essentially the minimum drag. Further, if the minimum drag-due-to-lift problem is analyzed from Kogan's[1]

point of view, using the reversed Mach wave as a control surface in applying the momentum theorem to the calculation of drag and obtaining the minimum drag criterion as a condition on the projected velocity distribution on this reverse characteristic surface, then according to M.D. VanDyke and R.T. Jones[2] the minimum drag criterion remains the same even when quantities of the second order in the velocities and pressures are retained.

Employing optimum camber and twist, the theoretical gains over the drag of a flat wing are not spectacular. For example, Germain[3] has shown that for a delta wing maximum drag reduction is obtained for the sonic-leading-edge case for which the wing with optimum warping has eleven percent lower drag than the flat wing of the same planform. This represents an increase in $(L/D)_{max}$ for the wing itself of approximately six percent; for the complete aircraft the percent improvement would be somewhat smaller, of course. For wings which are swept behind the Mach cone, it has been found that, by optimizing the wing load distribution, a camber surface is obtained which requires no leading-edge suction and yields theoretical drag-due-to-lift values slightly below those of the corresponding flat wing with full leading-edge suction[4]. This is potentially a useful result since it is known that the favorable leading - edge thrust predicted for highly swept flat wings is seldom (if ever) realized experimentally. This is because the very large local leading-edge lift force (corresponding to infinite velocities around the leading-edge) predicted by the theory is not physically possible; flow separation and/or shedding of vorticity then occur at the leading-edge, causing a different flow pattern around the wing than that which theory supposes. Hopefully, this breakdown of the postulated potential flow will not occur if the associated edge forces are nonsingular. It then may be possible to achieve the predicted low-drag of the optimally cambered wings.

Techniques for finding the minimum drag-due-to-lift, based on linearized theory, have been developed by Jones, Graham, Ward and others (Refs. 1 – 18). In general, criteria for minimum drag employ the concepts of combined forward and reverse flows, and they lead, at best, to rather difficult integral equations for the optimum lift distribution. Although the problem of finding the optimum loading on a planar wing in

supersonic flow has been solved in theory[11], calculations may be quite difficult to make. Exact results are known for only one or two special cases. Usually the solution is approximated in one way or another; examples of such approximations may be found in Refs. 12-18.

The methods of Cohen[17] and Grant[18] are of particular interest because of their straightforward simplicity. Cohen[17] assumes a double power series for the distribution of angle of attack, and minimizes the drag with respect to the coefficients of the series. The series is truncated so that only the first 6 to 10 terms are used. Grant, on the other hand, assumes a polynomial form of the loading. He applied Lagrange's method of undetermined multipliers to the problem of properly combining a finite number of lift loadings. He only used a four term polynomial, but chose terms which were apt to give the best improvement in drag due to lift. It is a modification of Grant's method which is used to design the wings described in this report.

C. EXPERIMENTS DESIGNED TO OBTAIN IMPROVED DRAG DUE TO LIFT

Although a great deal of experimental work has been done previously to find ways of predicting the wing load distribution due to a known camber and twist (see for instance Refs. 19 and 20), only a few previous investigations have been made to verify the validity of the procedures used to obtain improved drag due to lift. The real problem here is that only for wings with subsonic leading edges are lift-drag ratios of great interest predicted and, for these, viscous effects, which are hard to predict, play an important role in determining whether the flow follows the wing surface or separates from it.

Madden[21,22] was one of the first to obtain experimentally some of the improvement in drag-due-to-lift that theory predicts. He tested a 63° swept wing which was cambered and twisted to have a uniform load distribution (this wing has a lower drag due to lift than a flat wing). He found some improvement but not as much as predicted by theory. A similar investigation was made by Brown and Hargrave[23] with a wing-body combination. They designed and tested two wings with design uniform lift coefficients of .08 and .20 at Mach number of 1.23. For the first wing the lift-drag ratio

agreed with that predicted up to a lift coefficient of .1. The lift-drag ratio of the wing designed for C_L =.2 was lower than that predicted at all angles. Both wings gave approximately 10 percent improvement in the maximum lift-drag ratio when compared with flat wing data. This was less than the 25 percent improvement predicted.

Hallessy and Hasson[24] were apparently the first to test a wing that was designed to have an optimum drag due to lift. Their wing was designed by Brown and McLean of Langley Field, Virginia, using Grant's[18] procedure. The measured lift-drag ratio was 15 percent lower than predicted. It was felt that there was "supercritical flow (Mach No. > 1 normal to the loading edge) on the upper surface of the wing which produced large regions of flow separation"[25]. Therefore a second experiment[25] was conducted. The wing for this experiment was designed at Martin Company using the method of Ginzel and Multhopp[12]. This wing had a sweepback of 74° and was designed for M = 2.5 whereas the previous one was swept back 75° and was designed for M = 3.00. The results of the test[25] of this wing were again disappointing. The maximum lift-drag ratio was 14 percent below that predicted by theory. Another attempt to obtain an improved drag due-to-lift experimentally was made by Carlson[26]. Using the computation techniques developed by Clinton E. Brown and Francis E. McLean of Langley Research Center which were based on the method of Tucker[27] and Grant[18], several wings were built and tested at a Mach number of 2.05. Two 70° swept arrow wings with design lift coefficients of .08 and .16, respectively, and a 75° swept arrow with a design lift coefficient of .16 were built. These wings were swept far behind the Mach angle to avoid the supercritical flow mentioned above, but further the peak pressure coefficients were restricted to 1.4 times the average. Neither of the wings with a design C_L of .16 gave appreciable gain in lift-drag ratio, but the one with a design C_L = .08 did. This wing had a maximum lift-drag ratio of 8.8 at a lift coefficient of .14; whereas a flat wing had an $(L/D)_{max}$ = 8.1 at a C_L of .12. However the measured lift-drag ratio was still less than that predicted theoretically.

Later Carlson[28] measured the pressure distribution over these wings. These results confirmed the force results obtained above.

D. CURRENT PROGRAM

The work described in this report is another attempt to obtain experimentally some of the gain in drag due to lift which linear theory indicates is possible. Because of the current interest in a Mach number 3 supersonic transport, the wings were designed for that Mach number. Two planforms were investigated, an arrow and a double delta. The leading edge of the arrow wing and the inboard part of the double delta were swept back 78°. The outboard portion of the double delta was swept back 60°. Its tip was just inside the Mach cone from the wing apex.

Flat and warped versions of both wings were tested. The design procedure and the wind tunnel tests are both described in this report.

CHAPTER II

THE DESIGN OF WINGS WITH REDUCED DRAG-DUE-TO-LIFT

A. PLANFORM STUDIES

1. Introduction

Initial calculations were made using Grant's[18] procedure and a loading series of the same form as his, i.e.,

$$\frac{\ell(x,y)}{q} = a_0 + a_1 x + a_2 |y| + a_3 y^2 \tag{4}$$

The coefficients a_n were optimized to give minimum induced drag. (See Appendix I and Ref. 18) The calculations were carried out analytically as far as was practical, and then the integral formulas were programmed so that, essentially, the algebra reduction was carried out numerically by an IBM 709 (see Ref. 29 to 33).

One should bear in mind that these solutions are not absolute minima, but only the result of optimizing the above four term loading series. However the resulting drag rise factors for the arrow wing planform are reasonably close to the lower-bound derived by Jones[5]. For both the arrow and double delta wing the drag rise factors are sufficiently smaller than those corresponding to the uncambered wing (with no leading edge suction) to be interesting.

These solutions represent wings with singular camber-surface shapes. (This is particularly true of the double delta which has an additional singularity along the junction between the subsonic and supersonic section.) The drag-due-to-lift therefore may not be realistic in all cases. However since these calculations were made to gain experience and to learn about the effect of gross planform changes it was felt they would prove valuable, if caution was used in interpreting the results.

2. Arrow Wing Studies

The results obtained for the arrow wing, for the most part, repeat the work of previous investigators (18, 34, 35), except that the effect of cutting off the tip of the wing was also investigated. The notation and co-ordinates used for the arrow and double delta planforms are given in Fig. 1.

The effects of leading-and trailing-edge sweep on the drag-rise factor, $(C_D/C_L^2)_{opt.}$, of subsonic-leading-edge arrow wings at Mach number 3 are shown in Fig. 2. Only a small range of leading-edge angles was thought to be of interest at this high design Mach number, because wings with sweepback less than about 76° are apt to have problems associated with transonic flow phenomena (i.e., shock waves on the wing), while structural problems would seem prohibitive for wings swept back much more than about 80°. (For supersonic leading-edge wings, theory predicts only small improvement in lift-drag ratio by cambering and twisting the wing; hence, these were not of interest to this program.)

Calculations were made only for wings with supersonic trailing edges. (The equalization of pressures at a subsonic trailing edge causes large loss in lifting efficiency for flat wings; to compensate for this, the optimized wing demands excessive camber, leading to flow separation.) For a given leading-edge sweep angle, increasing the trailing-edge sweep (i.e., the cut-out ratio μ) always reduces $(C_D/C_L^2)_{opt.}$ and thus improves the lift-drag ratio. Again, structural considerations tend to limit the range of trailing-edge angles which may be considered practical. The improvement in lift-drag ratio due to increased trailing-edge cut-out is a result of eliminating area near the axis, where these conical-geometry wings are naturally inefficient, and leaving relatively more of the naturally-efficient leading-edge area. This effect is illustrated even more sharply by Fig. 3. (Negative μ - values correspond to forward sweep of the trailing-edge.)

Part (a) of Fig. 4 shows theoretical maximum lift-drag ratio as a function of aspect ratio for optimally cambered arrow wings having three-per cent-thick airfoil sections shaped to have minimum thickness drag for given wing volume[36]. A friction drag coefficient of .0021, based on wetted area, was assumed. These curves are related to the leading-and trailing-edge geometry of the wings in parts (b) and (c) of the figure. Again, the benefit of increased trailing-edge cut-out is apparent. The low-aspect-ratio cut-off of each of the curves corresponds either to aspect ratio = 1/2 or to the sonic trailing-edge condition; no calculations were made for smaller values of aspect ratio.

Figure 5 shows the effect of clipping the wing tip perpendicular to

the root chord on the optimum drag rise factor; μ_B is a measure of the trailing edge sweep. The line of constant μ, when combined with the rest of the curves in the figure, shows that any tip cut off is detrimental to the over-all drag rise factor. This is not surprising as the tip region, theoretically, is one of the most efficient parts of the wing.

3. Double Delta Wing Studies

The geometric parameters of the double-delta planform are sufficient in number so that a comprehensive study of their separate influences on the drag coefficient would have been lengthy. A few curves have been prepared to show the effect of varying some of these parameters for certain fixed values of the remaining ones. The curves again give the drag-rise factor which results in each case from optimizing the coefficients of the four-term polynomial loading of Eq. (4). This "optimum" drag is always significantly lower than the drag-due-to-lift of a flat wing of the same planform[37], but it may or may not be a good approximation to the true minimum drag of the planform. In fact, it actually is a rather poor approximation to the theoretical minimum drag, as will be shown, but it may lie near to a realistic, or achievable, low-drag value.

Figure 6 shows, for a wing of fixed leading-edge geometry, the effect of varying the trailing-edge sweep, as indicated by the dotted line on the planform sketch at the top of the figure. The maximum value of trailing edge sweep is reached when the trailing edge becomes coincident with the outer leading-edge. The benefit of cutting out the trailing edge as much as possible is apparent. This conclusion is consistent with the result shown previously for the arrow planforms.

Several other geometry changes were investigated. However, the possible gains due to planform changes were even smaller than that shown in Fig. (6). The detailed results of this investigation are given in Ref. (33).

In Fig. (7), the sweep of the inner leading edge is varied while the wing span, the trailing-edge geometry, and the chordwise position of the leading-edge juncture are held fixed. Thus, the sweepback of the outer leading edge has to vary also. Limits on the outer wing sweep, between the Mach cone value ($m_2 = 1$) and a value corresponding to the trailing edge sweep ($m_2 = 1/\omega$), limit the upper and lower values of m_1 for which the calculations could be made. For this figure more than for

the preceding one, it must be emphasized that the "optimum" drag coefficient plotted is the result of optimizing the loading given in Eq. (4), employing Grant's procedure as described in Refs. 18 and 30. Since, as will be shown, the four-term polynomial loading is not adequate, in general, to provide a good approximation to the true theoretical minimum drag of the double-delta wing, the results do not necessarily indicate the correct trends for the minimum drag coefficient.

In order to evaluate the effect on optimum drag coefficient of employing additional terms in the loading series, computations were made for one example, (having the planform geometry of the double delta wing used in the tests described in Chapter III (see Fig. 14)) using 4, 6 and 8 term polynomial loadings. These solutions were obtained by Mr. Roy Krupp, using the numerical methods discussed in Appendix II. The optimum loading coefficients and the resulting drag coefficients are shown in Table I. Some further drag reduction is obtained by including the additional terms in the load distribution, though the difference in drag between the 6 and 8 term loadings is very small - particularly if it is evaluated in terms of the extra effort involved to obtain such solutions. However, the growing magnitudes of the optimum coefficients in the loading series are objectionable in that they imply increasingly rapid changes of camber-surface shape and sharper curvatures, as well as undesirable pressure gradients. This growth in magnitude of the loading coefficients as the number of terms is increased is, of course, an indication of the fact that the optimum loading for this planform is not well represented by a polynomial expansion in the x,y-coordinates.

The preceding example indicates that a polynomial load distribution in powers of x and y does not converge well to a representation of the minimum drag loading for the double-delta planform. It is of some importance to be able to evaluate how well the drag coefficients plotted in the figures do approximate the minimum drag for this wing.

Certain drag minimization theorems (see Ref. 7, for example) give the result that, in linear theory, the minimum drag of a wing of given planform can be found as the solution of a two-dimensional potential problem whose boundaries are found by projecting onto a plane normal

to the flow direction the wing and the rim of its Mach envelope. (The Mach envelope is defined as the region which is disturbed by the wing in both forward and reverse flow. The rim of the Mach envelope is then the line of intersection of the envelope of Mach waves caused by the wing in forward flight with the envelope of Mach waves caused in reverse flight.) Thus, planar wings which have the same Mach envelope and the same maximum span must have the same value of minimum drag for a fixed total lift. This means that, for wings with the planform geometry constraints we are considering, the minimum drag is determined by the "skeleton" of the wing, i.e., by its trailing edge and root chord. In the example sketched in Fig. 8, all of the wings have the same minimum lifting drag, D_{min}/L^2. The drag-rise factors, $C_D/C_L{}^2$, are then related in proportion to the areas of the wings, being a maximum for the simple arrow wing on the left and decreasing to zero (theoretically) for the skeleton wing on the right. [This is an opposite trend from the conclusion one might have drawn from Fig. 7 which is the result of optimizing only a four-term polynomial loading.] Obviously, if the wing is to support the same total lift on a smaller and smaller area, the loading must become more and more locally concentrated in the progression from the wing on the left to that on the right, and the theory then might be expected to become less reliable in its description of the actual flow pattern. Also, as the minimum-drag loading becomes more singular, the four-term polynomial of Eq. (4) is less able to represent it with any accuracy. [This explains why Fig. 7 does not show even the correct trend for theoretical minimum drag coefficient.]

Also apparent from the preceding remarks is the fact that, if the minimum drag of the arrow wing is known, the minimum drag of the double delta wings may be found from it by simply proportioning the areas of the wings. In Fig. 9, the solid curve shows Grant's solution[18] for the minimum drag coefficient of simple delta wings. [This is not an exact solution but is also the result of optimizing the four-term polynomial loading; however, it is known, from the work of Germain[3] and of Jones[5], to be a good approximation to the minimum drag coefficient for this planform.] The other curves in Fig. 9 show the minimum drag coefficients of certain double delta planforms; these results were obtained

by multiplying the ordinates of the delta-wing curve by the appropriate area ratios. The points spotted on the figure indicate some drag coefficients obtained by calculations optimizing the four-term polynomial loading; they lie above the minimum-drag values considerably. With only four terms in the loading, the "optimum" drag coefficients remain about the same as for the original delta planform. However, because the theoretically optimum loadings appear to have undesirable concentrations of local lifting pressures (and/or highly singular camber surface shapes), the true minimum drag values as given by linear theory probably are not realistic values to try to design for. Even the low-drag values computed by Grant's method, employing only a small number of polynomial loadings, may be nonconservative.

The foregoing is a brief summary of the studies carried out to investigate the effects of planform on the possible gains in drag rise factor which might be obtained by twisting and cambering the wings.

The details of these studies are reported in a series of internal memoranda (Refs. 29-33) which are available on request. Much of the analysis required for programming the double delta wing is contained in these reports.

B. CALCULATIONS OF THE WARPED SHAPES OF THE ARROW AND DOUBLE DELTA PLANFORMS WITH IMPROVED INDUCED DRAG

1. Use of Aerodynamic Matrices

When this program was first started, the personnel at the Aerophysics Laboratory had had considerable experience using aerodynamic matrices for predicting the aerodynamic loading on wings with camber and twist[20,38]. These techniques are simple mathematically and the added versatility gained because one method could be used for all planforms made them appear very attractive. However it was found that the accuracy depended greatly on the number and distribution of planform subdivisions. Further, for any practical number of subdivisions the a_n in the loading series (Eq. 4) were quite different and the drag rise factor better than those obtained using Grants[18] analytical method (i.e., were erroneously low). There just wasn't enough storage in the available computing machine to enable the use of a sufficient number of area divisions unless a judicious selection of size and distribution

was used. It was felt this would involve a lot of study. Therefore this technique was dropped and we went to the method described below. The attempts to use matrices are described in detail in Ref. (39).

2. General Considerations Which Led to the Approach Used

Before describing the design technique actually used to obtain the physical shapes of the optimum arrow and double delta wing, it is of interest to consider some of the factors which led us to the design procedure. What follows are mostly direct quotes from Ref. 40.

Measurements of lift-drag ratios for arrow wings employing twist and camber have yielded values far below those estimated on the basis of linearized theory (Ref. 26). The measured load distributions (Ref. 28) indicate quite good agreement with the theoretical distributions over a large part of the wing, but show marked loss in lifting pressure difference (compared with theory) at the more outboard pressure taps and in the vicinity of the wing leading edge. These discrepancies were believed to be due to three causes: (1) separation and related effects due to viscosity, particularly the formation of separated vortices near the wing leading edge, (2) neglect of second and higher order terms in the theory, (3) the failure of the theoretical solutions which predict infinite perturbation velocities in the neighborhood of the leading edge and near the axis of the wing.

The following paragraphs discuss these sources of discrepancy in somewhat more detail and attempt to establish their relative importance and means of correction where available. A design method is described which employs linear theory but which enforces everywhere on the planform the basic requirement of small perturbation velocities. Some examples of low drag wings designed in this way are given; these indicate that constraints on the allowable magnitude of the perturbation velocities tend to increase the theoretical drag coefficient. Successful design then requires that such constraints be adequate but at the same time not unnecessarily conservative.

3. Separation and Viscous-Related Effects

Non-linearities due to viscous effects are believed to be the most important of the three causes listed to explain the disagreement between

theoretical and experimental values of the drag coefficient for lifting wings at supersonic speeds. Unfortunately, these are also the most difficult either to remove or to account for. Potential flow theory neglects viscosity entirely so it cannot correct for such discrepancies. Since separation and vortex detachment occur when local pressure gradients and lifting pressures become excessive,(for instance potential theory can predict pressures lower than a vacuum) they might be avoided by placing suitable constraints on these latter quantities in the potential flow design procedure. However, no reliable criteria are known to us for assuring wholly attached flow over the highly swept planforms which are of interest here; hence, constraints on maximum pressures and pressure gradients must be largely a matter of judgment. Ultimately, solution of this part of the problem probably will be found empirically and will involve long and careful experimenting. It is possible, of course, that the constraint conditions required to maintain the type of flow which the theory describes are so severe that better wing efficiency might be obtained by employing a design procedure which admits the presence of detached vortices on the suction side of the wing. It appears that the British already are considering a semi-empirical approach to the problem on this basis (Ref. 41).

It was reported to us by J.G. Jones that the British researcher, E. Maskell, had developed a criterion for avoiding vortex detachment at the leading edges of wings which are sufficiently swept for the slender-wing type of aerodynamic analysis to be applicable. However, his work was not found in time to be of use.

4. Second-Order Effects

The drag coefficient is generally assumed to be expressible as a parabolic function of the lift coefficient for a given Mach number and wing planform

$$C_D = C_{D_0} + \frac{dC_D}{dC_L{}^2} C_L{}^2 \qquad (5)$$

Here, C_{D_0} is the zero-lift drag and $\frac{dC_D}{dC_L{}^2}$ is the drag rise factor. This equation is applicable either to an isolated flat wing or to the family

of wings which at any value of C_L has the lowest possible drag. (It is NOT, of course, an equation for the variation of drag with lift for an isolated member of the family of minimum-drag wings, that is, a wing which has a fixed twist and camber.) Maximum lift-drag ratio, then, is written:

$$(L/D)_{max} = \left[4\ C_{D_0} \frac{dC_D}{dC_L^2} \right]^{-1/2} \tag{6}$$

Thus, maximum L/D obviously is increased by reductions either in C_{D_0} or in dC_D/dC_L^2.

In experimental checks (Ref. 26) of wings which are cambered and twisted for low drag, the theoretically-predicted low values of the drag-rise factor dC_D/dC_L^2 have not been achieved, and consequently the maximum lift-drag ratios have been low.

In this section we are concerned with second-order effects on the drag-rise factor. This is not strictly consistent, perhaps, since the above equations are first-order relationships, but we wish to determine whether the neglect of second-order effects in the design procedure can account for the very large discrepancy between measured and predicted values of the incremental drag due to lift.

Consider first the very simple case of a symmetric single-wedge airfoil at angle of attack in two-dimensional flow. To second order, neglecting base effects, the lift and drag coefficients are determined by the well-known Busemann formulas as:

$$C_\ell = \alpha\ (k_1 + 2k_2\ \delta) \tag{7}$$

$$C_d = \alpha^2\ (k_1 + 3k_2\ \delta) + \delta^2\ (k_1 + k_2\ \delta). \tag{8}$$

where:

$$k_1 = 4/\sqrt{M_\infty^2 - 1} \tag{9}$$

$$k_2 = \frac{(\gamma + 1)\ M_\infty^4 - 4\ (M_\infty^2 - 1)}{(M_\infty^2 - 1)^2} \tag{10}$$

The second term in the C_d-expression is the thickness drag of the airfoil; it is present even at zero angle of attack, that is, when there is no lift. The first term is the incremental drag which occurs when the airfoil is lifting. The first part of it, $\alpha^2 k_1$, is the drag of the airfoil in linear airfoil theory. The second part, $\alpha^2 (3 k_2 \delta)$ is the second order contribution to drag due to lift; it expresses the interaction between the airfoil thickness and its angle of attack. Similarly, in the expression for lift coefficient, αk_1 is the linear theory contribution while $\alpha (2 k_2 \delta)$ represents the thickness interaction on lift. Hence, to second order, the total increment in drag attributable to lift is:

$$\frac{\Delta C_d}{C_\ell^2} = \frac{k_1 + 3k_2 \delta}{(k_1 + 2k_2 \delta)^2} \tag{11}$$

For small thickness this is approximately:

$$\frac{\Delta C_d}{C_\ell^2} \approx \frac{1}{k_1} \left(1 - \frac{k_2}{k_1} \delta\right) \tag{12}$$

Note that the factor $1/k_1$ is the linear theory result which is modified by the quantity in parentheses to account for second-order effects. Hence, for this example, second-order theory actually predicts a <u>decrease</u> in drag rise factor as compared to the first-order result. (However, C_{D_0} is increased by the second-order term. Note also that for a symmetric double wedge airfoil there is no second-order effect on drag due to lift.)

The general, three-dimensional, cambered wing case is not this simple, of course. Precise second-order analyses even for flat three-dimensional wings with supersonic leading edges (Ref. 42) are already so complex as to discourage contemplation of this approach for the inverse design problem. The subsonic leading-edge case seems even more formidable (Ref. 43).

We therefore consider an <u>approximate</u> correction for taking into account second-order (or thickness) effects on the pressure distribution of a cambered wing. It is assumed that the wing planform without thickness (that is, the mean camber surface) is designed to have, within linear

theory, a specified loading. This loading is achieved through an antisymmetric pressure distribution which results from the camber and twist of the wing. (The loading might be, for example, an optimum as determined by linear theory.) We wish to determine how the wing loading is altered by the addition of a thickness distribution which is symmetric above and below the mean camber surface.

Since the original pressure distribution is specified, the local Mach number (M) and dynamic pressure (q) on the upper and lower sides of the mean camber surface are known. We make the crude approximations that the local velocities are parallel to the plane containing the free-stream velocity vector and that, for the purpose of finding the effect of thickness on lift, the local pressure change due to the wing thickness may be computed as a two-dimensional deflection of the flow, at its local Mach number, through an angle δ which is the local slope of the wing surface, measured with respect to the mean camber surface. Thus, based on local velocity, the pressure coefficient due to thickness is

$$C_p' \equiv \frac{\Delta p}{q} = \frac{2\delta}{\beta} \tag{13}$$

where $\beta = \sqrt{M^2 - 1}$. Based on the free-stream velocity, however, this represents a change in pressure coefficient of

$$\Delta C_{p\infty} \equiv \frac{\Delta p}{q_\infty} = \frac{\Delta p}{q}\,\frac{q}{q_\infty} = \frac{2\delta}{\beta}\,\frac{q}{q_\infty} \tag{14}$$

Denoting upper surface quantities by the subscript t and lower surface quantities by subscript b, the change in loading due to the thickness of the wing is in this approximation given as

$$\frac{\Delta \ell^{(2)}(\delta)}{q_\infty} = 2\delta \left[\frac{1}{\beta_b}\,\frac{q_b}{q_\infty} - \frac{1}{\beta_t}\,\frac{q_t}{q_\infty} \right] \tag{15}$$

Note that δ as well as β_b, β_t, q_b, q_t, is a function of the x, y coordinates on the wing. If the local Mach number and dynamic pressure are expanded

in terms of the free-stream Mach number we have, to first order,

$$M^2 = M_\infty^2 \left[1 + 2\phi_x \left(1 + \frac{\gamma - 1}{2} M_\infty^2 \right) + \ldots \right] \quad (16)$$

$$\frac{q}{q_\infty} = 1 + (2 - M_\infty^2)\,\phi_x + \ldots \quad (17)$$

where ϕ_x is the perturbation velocity which is proportional to the original (anti-symmetric) linear-theory pressure distribution on the zero-thickness wing and γ is the ratio of specific heats for air. Substituting these relations into **Eq.** 15 and noting that $\phi_{x_t} = -\phi_{x_b} = \ell_{\text{linear}}/4q_\infty$ where ℓ_{linear} is the linear theory loading, the second order correction for lift due to thickness is :

$$\frac{\Delta\ell^{(2)}(x, y)}{\ell_{\text{linear}}(x, y)} = \frac{\delta(x, y)}{\beta_\infty^3} \left[2(1 - M_\infty^2) + \left(\frac{\gamma + 1}{2}\right)(M_\infty^4) \right] \quad (18)$$

That is, the corrected loading (really, the normal force distribution) is :

$$\ell(x, y) = \ell_{\text{linear}}(x, y) \left[1 + K\,\delta(x, y) \right] \quad (19)$$

where:

$$K = \left[(\gamma+1) M_\infty^4 - 4\beta_\infty^2 \right] / 2\beta_\infty^3 \quad (20)$$

In the inverse problem, it is desired to <u>design</u> a wing for a prescribed normal force loading, $\ell(x, y)$. One may then use linear theory to find the camber-surface geometry, $\alpha^*(x, y)$, corresponding to a fictitious loading

$$\ell^*_{\text{linear}}(x, y) = \ell(x, y) / \left[1 + K\,\delta(x, y) \right] \quad (21)$$

The drag in this case is then, to the same approximation, the integral of the product $\ell(x, y)\,\alpha^*(x, y)$ over the planform area.

It will be observed that the correction factor appearing in Eq. (19) is just that arising in Busemann's two dimensional second order theory, but the multiplying factor, ℓ_{linear}, is found for the three-dimensional wing. This results, of course, from the simplifying approximations made. It should be noted that for thin wings the correction is small. Hence it may be relatively inaccurate and still represent a significant correction to the loading. (E.g., an error as high as 10 or even 20 percent in a correction which is itself only 10 percent of the total lift still represents an important improvement.) Comparison of results from Eq. (19) with available data generally shows good agreement.

There is, of course, a second-order term due to the camber angle itself, but this contributes an added pressure distribution which is usually symmetric on the upper and lower sides of the wing, and hence it contributes nothing to the normal force distribution. An excepted region is the neighborhood of the Mach lines which bound the region influenced by discontinuities in the slope of the planform boundaries or surface; here a uniformly-valid second-order solution results in different displacements of the local Mach lines on the upper and lower wing surfaces and therefore the added second-order pressures are not quite symmetric (Ref. 42).

The net effect of the second-order correction on the drag-rise factor will depend on the distribution of thickness and of normal force. For thin, closed airfoils it will usually be negligible.

The above approximate correction was not used in the design of our wind-tunnel models for several reasons. Among them are: (1) for thin wings the correction is small and relatively unimportant, except near the leading-edge where solution in powers of a small perturbation parameter is not valid anyway; (2) comparisons with data for flat and warped wings indicate that over the aft part of the wing where the airfoil thickness is decreasing and the second-order correction to normal force would be negative, it is partially or wholly compensated by an increase

in "apparent" thickness due to growth of the viscous boundary layer; (3) our chosen airfoil shape (NACA 65A series) is such as to place rather severe strain on the accuracy of the numerical computation methods which would compute α^* (and C_D) corresponding to the loading of Eq. 21 (see Appendix II); this could be alleviated but the time and expense seemed hardly justified in view of the relative unimportance of this correction and the relatively greater importance of viscous effects.

5. Effects of Constraining the Perturbation Velocities

The third cause for discrepancy between theory and experiment has to do with local failures of the theoretical solution. It is well-known, for example, that thin-wing theory predicts infinite pressure at the subsonic leading-edge of a flat lifting wing. Similarly, though low drag wings are usually designed to have finite pressures everywhere, for the types of loadings which are usually prescribed, theory predicts infinities in the upwash velocities at some points on the planform. For example, the polynomial loading

$$\frac{\ell(x,y)}{q_\infty} = a_0 + a_1 \frac{x}{\ell_0} + a_2 \left(\frac{x}{\ell_0}\right)^2 + a_3 \left|\frac{y}{b}\right| + a_4 \left(\frac{y}{b}\right)^2 \qquad (22)$$

results, in linear theory, in infinite upwash (or downwash) all along the subsonic leading edge of a triangular wing and along the root chord (or along any chord following an abrupt change in the angle of sweep of the leading edge). Although the latter singularities are logarithmic and therefore weaker than the leading-edge pressure singularity for the flat wing case, they nevertheless represent failures of the thin-airfoil theory which cannot possibly be realized experimentally.

Ordinarily, this type of local breakdown of the theoretical solution is important only in a very small region of the wing and has little effect on the overall integrated forces. If, however, the large predicted local velocities indicate a sufficient violation of physical conditions to change the type of flow pattern from that which has been presumed, then all or a large part of the wing may be affected and we are led back to the problem

described in the section preceding the last one. For the drag-reduction problem, any departure of the flow from the smooth attached flow presumed by the theory is particularly serious, even though it occurs only in a limited region near the leading edge. This is because the low drag values predicted by theory are achieved by supporting very large local normal forces on just this area of the wing (the leading-edge neighborhood) where, due to the positive camber, the local normal force vectors have forward components. Thus, for theory and experiment to agree, it is important that the theory be applied only to a physically realizable flow situation.

Lighthill (Ref. 44) and VanDyke (Ref. 45) considered methods for making thin-wing theory uniformly valid for wings with prescribed thickness and camber. The inverse design problem is somewhat simpler in that there are an infinite number of pressure distributions for which thin-airfoil theory predicts finite perturbation velocities everywhere on the planform. It is necessary only that the prescribed load distribution go smoothly to zero at the leading edge (as required physically) and fulfill certain smoothness requirements along the root-chord (and at the inner-outer wing juncture in the case of the double-delta planform). For example, a modification of the above loading (Eq. 22) to give finite perturbation velocities at all points of a triangular wing is:

$$\frac{\ell(x,y)}{q_\infty} = \frac{x^2 \tan^2\epsilon - y^2}{(x+c)^2 \tan^2\epsilon - y^2}\left[a_0 + a_1 \frac{x}{\ell_0} + a_2 \left(\frac{x}{\ell_0}\right)^2 + a_3 \frac{y^2}{y^2+\lambda}\left|\frac{y}{b}\right| + a_4 \left(\frac{y}{b}\right)^2 + \ldots \right] \tag{23}$$

where c and λ are small constants and ϵ is the angle the leading edge makes with the flow direction (see Fig. 1 for coordinate system and geometry definition). Here, the factor ahead of the bracket drops the loading smoothly to zero at the leading edge and thus ensures finite perturbation velocities there. The factor multiplying $|y|$ removes

the discontinuity in first derivative of this loading at $y = 0$, thus eliminating further infinities in upwash velocity along the root chord of the wing.

Although the loading given in Eq. (23) corresponds to there being finite perturbation velocities everywhere, these velocities may still have very large local magnitudes. The velocity magnitudes can be made smaller by increasing the constants c and λ, but this also decreases the lifting efficiency of the wing. The local velocities may be varied also by changing the type of loading used. Thus, the problem of designing a wing for low drag by this method is in good part one of trial and error wherein we seek an appropriate loading with enough free parameters so that one may optimize some of the parameters for low drag while at the same time constraining the others so that the final solution violates none of the assumptions on which its derivation is based. Such a solution - that is, one which fulfills the limitations of small perturbation theory - probably is required if the high drag penalties due to shock formation and flow separation are to be avoided.

6. The Design of the Wind Tunnel Models

In the absence of known criteria for avoiding separation and other undesirable phenomena on the highly swept planforms of interest to this study, we used only a simple criterion to limit the perturbation velocities, namely, that the approximation

$$\alpha(x, y) \approx \tan\left[\ \alpha(x, y)\ \right] \approx -\ w\ (x, y)/U_{\infty} \qquad (24)$$

be valid everywhere (w is the upwash velocity). In addition, since our purpose is to design wind tunnel models, it was required that the solution be considered "buildable" by the structural designers and machine shop people; this meant, generally, that the spanwise slope dz/dy, especially at the wing root, must not be so great as to cause structural problems or to interfere with the placing of pressure tubing in models of the size and geometry being used. Finally, the loadings were required to be "reasonably smooth" since chordwise waviness

in the pressure distribution would imply the undesirable feature of having several compressions on the wing.

Trailing-edge ordinates corresponding to several loadings on the arrow wing wind tunnel model planform (Fig. 10) are shown in Fig. 11. The design Mach number is 3 and the curves are plotted for a design lift coefficient, $C_{L_{des}}$, of 0.1. The numerical coefficients (a_0, etc.) multiplying each term in the various loadings are the optimum coefficients resulting in least drag of the loading, as determined by Grant's method of Lagrange multipliers (Ref. 18). Solutions for drag and for airfoil ordinates were obtained by Mr. Roy Krupp, using the numerical procedures described in Appendix II. Since the specification of wing loading leads, in linear theory, only to the determination of camber surface slope, dz/dx ($dz/dx = -\alpha$), there is an arbitrary function of the spanwise coordinate y available in determining the surface ordinate z; for convenience this arbitrary function was selected so that the leading edge of the wing is at $z = 0$. Thus, the trailing edge ordinates plotted in the figures indicate roughly the amount of wing warp between leading and trailing edge. (Actually, the camber is generally positive, so that chordwise plots of the camber surfaces show slightly positive values of z just back of the leading edge, reaching a maximum and then decreasing through zero to negative values further aft. Some of the solutions even reflex slightly near the trailing edge; hence, the plot of trailing edge ordinate is not necessarily a plot of maximum deflection, but the differences are not great.)

All of the solutions plotted (except the standard unconstrained one corresponding to Eq. 22) obey the small perturbation criterion, Eq. (24)*. Not all of them satisfy the criterion of being "buildable". This latter requirement finally induced us to drop the a_0 – term from Eq. (23),** even though this term seemed desirable from the viewpoint of limiting

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* The maximum slope permitted was about 0.2 radians, negative local angle of attack, occurring at the wing leading edge, outboard. More stringent restrictions on wing slope affect the drag values even more adversely than is obtained for these examples.

** In retrospect, this is thought to be an error of judgment. (See page 46)

the pressure gradients. (Modifying the term to the form

$$a_0 \quad \frac{x^2}{x^2 + c}$$

was somewhat helpful but not adequately so.)

Plots of chordwise loading at the wing root and at one outboard station ($y/b = .85$) are shown in Fig. 12 for the purpose of showing graphically the type of modification being made to the load distribution. (x/c denotes distance from the leading edge as a fraction of local chord length.) The actual shape of the camber surface of the arrow wing is given in Table II and Fig. 13.

Trailing-edge ordinates as derived for several different loadings on the double-delta wind tunnel model planform are shown in Fig. 15. (The loadings are listed in the table at the end of each figure and may be indentified with the appropriate curve by the letter symbols. The coordinates in the loading formulas are non-dimensional, of course.) These also are plotted for design lift coefficient 0.1 at Mach number 3. As the sketches indicate, considerable difficulty was experienced in finding a loading which satisfactorily smoothed the outboard hump for this planform, without increasing the drag-due-to-lift unreasonably. (Only a few of the examples tried are plotted in Fig. 15.) The most satisfactory loadings were those with conical variation about the leading-edge crank (suggested by R. Krupp) and even these are considered only marginally "buildable". A more extensive investigation of possible loading formulas for this planform would be desirable, but could not be carried out at this time. (The calculations are fairly lengthy in terms of computing machine time and are therefore expensive.)

It will be noticed that a considerable penalty in drag coefficient is incurred for the double-delta planform by the constraint of small perturbation velocities. However, the final coefficient, $C_D/C_L^2 \approx 0.70$, is in the neighborhood of what the drag of the flat wing of the same planform would be if full leading-edge suction were achieved over the subsonic portion. We believed, therefore, that this was a reasonably low value of drag coefficient to try to design for, and that the much

lower minimum drag value predicted by linear theory for this wing was not realistic.

The ordinates of the camber surface of the double delta wing are given in Table III. Figure 16 shows both chordwise and spanwise cross sections of the wing.

CHAPTER III

THE WIND TUNNEL TESTS OF THE WINGS

A. DESCRIPTION OF THE APPARATUS

1. The Flat and Warped Arrow and Double Delta Wings

A flat and a warped version of both the arrow and double delta wings were tested. The flat and warped models of each planform were identical except for the camber and twist. The camber and twist of the warped wings was determined using the methods described in Chapter II. All the models were half-span and were made of solid steel with cutouts and slots to contain the pressure tubing. The pressure tubing was soft soldered into place and the remaining voids filled with epoxy.

Figure 10 is a drawing of the flat arrow wing and shows the location of the pressure taps for both the flat and warped wings. The leading edge of the arrow wing is swept back 78° to obtain subsonic, subcritical flow at the leading edge. Its full span aspect ratio is 1.143. The airfoil section is a NACA 65A004. Each side of the wing is instrumented with 65 pressure taps as shown in the figure. Note however that because of the extreme thinness of the wing the top and bottom pressure taps were slightly displaced at the most outboard chordwise row of taps. The bottom pressure taps were .080 inches or 2.3% of the chord further downstream than is shown in the drawing, for both arrow wings. Table II gives the ordinates of some chordwise stations of the warped arrow wing and cross sections in both the chordwise and spanwise directions are given in Fig. 13.

A drawing of the double-delta wing showing the location of the pressure taps is presented in Fig. 14. This wing was instrumented with 63 pressure taps on each side. Due to a mixup during construction of the flat model the top taps of the most outboard stations, instead of the bottom, are .080 inches or 4% further downstream

than the bottom ones which are shown in Fig. 3. On the warped wing it is the bottom taps which are displaced. The double-delta wing has a straight trailing edge, but its leading edge is swept back 78° for 41.5% of the span and 60° for the remainder. Its full span aspect ratio is 2.26. The ordinates of some spanwise stations of the warped double-delta wing are given in Table III and both spanwise and chordwise cross sections are shown in Fig. 16.

2. The Wind Tunnel

The measurements were made in the wind tunnel of the Naval Supersonic Facility at M.I.T. The characteristics of the wind tunnel follow:

Operating cycle	Continuous
Test section	18 in x 24 in subsonic (0.3 to 0.75) 18 in x 18 in transonic (0.7 to 1.2) 18 in x 24 in Mach 1.5 to 2.5 18 in x 18 in Mach 2.75 to 4.0 12-in diameter at Mach 7.6
Nozzle blocks available	Mach numbers 1.5, 1.7, 2.0, 2.25, 2.5 2.75, 3.0, 3.5, 4.0 and 7.6. Also subsonic and transonic blocks for a continuous Mach number range from M = 0.3 to 1.2.
Test-section window size	30-inch (24-inch diameter largest currently available)
Optical apparatus	30-inch schlieren or shadowgraph
Balance	Strain gage with automatic readout
Computer	Bendix G-15 digital computer
Mach number range	0.3 to 7.6
Reynolds number range	0.02×10^6 to 10×10^6/ft 0.3×10^6 to 0.7×10^6/ft at M = 7.6
Stagnation pressure range, P_0	0.75 to 42 psia 30 to 100 psia at M = 7.6
Stagnation temperature range, T_0	60 to 900°F (normal operating temperature 110°F, 750°F at M = 7.6)
Compressor drive	Electric motors 10,000 hp rated 12,500 hp for 2 hours
Main compressors	4,000 hp 4-stage centrifugal 6,000 hp 4-stage centrifugal Operable in parallel or series

3. The Model Mount and Measuring Systems

The models were mounted on a side-wall reflection plane 6 1/2 inches away from the wind tunnel wall. This boundary layer plate was built especially for this program. The mounting system was designed so that both pressure and force data could be taken simultaneously, although eventually a pure force run was made on all wings to check that the force data taken with the pressure tubing on was valid. The Boeing side-wall strain gage force balance (Ref. 46) was used for measuring the forces. This balance is unusual in that the various forces and moments are separated by means of flexure points before being measured on strain gage arms. Thus the balance is similar to the mechanical balances often used for subsonic testing and there is almost no interaction between lift, pitching moment, or drag. Also, deflections at the model are minimized. For instance the maximum change in angle of attack due to lift and pitching moment was .03° and the maximum motion of the forward tip of the wing away from the plate, due to drag and all other forces, was .003". There was, however, about 1/32 of an inch up or down motion for the maximum lift force.

Figure 17 is a schematic showing the arrow wing mounted on the boundary layer plate. Note that because of the 5" long attachment of the wing (called the foot from here on), it was necessary to have a circular section of the boundary layer plate move with the wing. This circular section is a part of a fairing which is attached to the angulating mechanism but not to the balance.

The pressures were read on two 110 inch 40 tube manometers, each of which was used twice to measure all the data at each angle. A special switching system for the pressures was built for this purpose. The tubes were connected so that corresponding top and bottom pressure taps were read on adjacent manometer tubes. Pressure taps on the first, third, and fifth spanwise stations were read first and those on the second, fourth and sixth last. The manometers were filled with 10 cs silicon fluid* with a specific gravity of about .94. The data was recorded photographically and reduced later.

The majority of the force data was recorded automatically using the standard equipment at the laboratory.

* Dow Corning Co., Midland, Michigan

B. THE WIND TUNNEL TEST

1. Introduction

All the data was taken at a Mach no. of 3. The test for each version of each wing may be considered to consist of three parts:

(1) A flow visualization study to examine the detailed flow over the wing

(2) A pressure test. This test was designed to obtain pressure data for several conditions of the wing. Force data was also taken on these runs, but was not considered valid until checked out by the force runs, because there were very large tare loads due to the pressure tubing connections.

(3) A force test to obtain valid force data

In order to obtain a record of drag vs. stagnation pressure or Reynolds number, the drag and stagnation pressure at zero angle of attack were recorded by hand at two psia intervals on a number of runs for the flat wings. Since it was also necessary to have the lift data for the optimum wings, this data was obtained using the standard equipment for those runs. In both cases no attempt was made to stabilize the pressure, but the data was taken as the tunnel pressure was being increased from the low starting level required to avoid damaging the strain gage balance or wings.

2. Flat Arrow Wing Test

The flat arrow wing was tested first. Since the boundary layer reflection plate had not been run before, one of the purposes of the first run was to see that this plate did not block the wind tunnel flow and that the flow over it was normal. For this test and all the other flow visualization tests, a mixture of lampblack and oil was painted on the leading edge of the splitter plate and wing. In the later runs it was also put around the root of the wing. The pressure taps were covered with tape.

The first two runs showed that the flow over the splitter plate was satisfactory, but that high pressure air from in back of the plate leaking through the gap at the leading and trailing edge of the wing foot was separating the flow over the aft part of the root of the wing. These two gaps were reduced from about .060 inches to less than .030 inches after Run 2. Later in the test, between Runs 9 and 10, they were further

reduced to about .010 inches.

For these flow visualization runs the wing angle of attack was set and the wind turned on. The stagnation pressure was raised to 30 psia and reduced to about 7 before turning the tunnel off. Then after the wind tunnel door was opened, pictures were taken of the resulting patterns on the wing and splitter plate. Data was obtained at angles of attack of 2°, 4°, 0° and 6° on Runs 1 to 4, respectively.

Runs 5 to 11 were used to obtain pressure data on the flat arrow wing. All were run at a stagnation pressure of 30 psia. Runs 5 and 6 are parts of the same run except that the reference pressure on the manometers developed a leak during Run 5. All the data (at $\alpha = -2°$, $-1°$, and 0°) of Run 5 was repeated in Run 6. Data was taken at $\alpha = -2°$, $-1°$, 0°, 1°, 2°, 3°, 4°, 5°, 6°, 7° and 9° in Run 6.

For Runs 7 to 11, first a boundary layer trip was added (Run 7), its size doubled (Run 8), then the trip was removed and the gap between wing and splitter plate and fairing filled with wax (run 9). When the data from run 9 showed that the gap between the leading edge of the foot of the wing and the fairing was still allowing some high pressure air to escape from in back of the splitter plate and perhaps separate the boundary layer, this gap was reduced to about .010 inches for runs 10 and 11. Run 10 was a partial repeat of 6. In run 9 data was obtained only at $\alpha - 2°$, because the wing was waxed to the splitter plate. In run 11 it was only waxed to the fairing and the splitter plate was covered with Apiezon grease* over the area where the foot moved to prevent the flow of air between the root chord of the wing and the splitter plate. Unfortunately the Apiezon bubbled and became rough.

Runs 12, 13 and 14 were all force runs and for these runs the pressure tubing was disconnected and plugged so as to cause no tare forces on the wing. Run 12 duplicates the conditions of 6, run 13 duplicates the conditions of 8, and for run 14 the boundary layer trip size of runs 8 and 13 was doubled again.

* Made by Metropolitan-Vickers Electrical Co., Ltd. Sold in US by James G. Biddle Co., 1316 Arch St., Philadelphia, Pa.

The boundary layer trips used in this program were a row of triangles of scotch tape*. These triangles were formed by gluing several layers of tape together and cutting the edge of the tape with pinking shears. The tape was stuck to the wing with the triangles in place. Then the tape was cut with a razor blade near the foot of the triangles (leaving about 60 percent of the base) and the unpinked edge removed, leaving a neat row of triangles at the proper place on the wing.

For these tests the cut edge of the triangles was parallel to and nearest to the leading edge of the wing. The trip thicknesses were determined using Ref. 47. 2**, 3, 4, and 8 thicknesses of tape (about .0043, .0065, .0086 and .0170 inches thick) were used. This sort of trip has been used previously at the Ames Research Center, NASA, and by North American Aviation Co. This kind of trip is both three-dimensional and repeatable.

3. The Flat Double Delta Wing Test

The test of the flat double delta was similar to that of the flat arrow except that the gaps around the foot of the wing were made as small as possible before the test and only a 4 thickness trip (.0086 inches) was ever used. Runs 15 and 16 were flow visualization runs at $\alpha = 2°$ and $4°$. Run 17 was the first pressure run but the wind tunnel developed a water leak in the cooler and so 18 is a repeat. In run 19 a trip was added and for run 20 the gap around the wing was sealed. A slightly different technique was used this time. The wing was waxed to the fairing to seal the gaps there, but the gap between the wing root and boundary layer plate was sealed by applying layers of tape to the root, between the root and plate, until the maximum clearance was always less than .002 inches.

Runs 21, 22 and 23 are identical force runs with a .0086 inch boundary layer trip. They were run to investigate some asymmetries in the drag data which were thought to be due to fouling in the balance due to metal chips. Data was taken from $\alpha = -6°$ to $+9°$ in one and two degree increments.

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*No. 810 Magic Mending Tape made by Minnesota Mining and Manufacturing Company, St. Paul, Minn.

**A two thickness trip was mounted 1" back from the leading edge of the splitter plate for all runs.

increments.

4. Test of the Warped Arrow Wing

The tests of the warped versions of the arrow and double delta wings were run nearly a year after those of the flat ones. The same equipment was used except that a new, more sensitive drag beam was built for the Boeing wall balance. As before, the arrow wing was tested first. The first run was a flow visualization run with the wing at zero angle of attack, which was defined as the angle for the design maximum lift-drag ratio. In the second run the pressure data was obtained at several angles for the wing with no trip. Using the results of the first test a three thickness trip was put on for run 3 and the data of Run 2 repeated. Runs 4 and 5 were force runs, the first with the trip on and the second without it.

5. Test of the Warped Double Delta Wing

For the test of the warped double delta, the pressure runs without and with a trip (3 thicknesses) were taken first, then the force runs and finally the flow visualization run. The flow visualization run was taken last because it was found impossible to obtain good pictures of the top surface of the optimum arrow wing while it was in the tunnel. By running this test last for the optimum double delta the pressure tubing was off so that it was possible to remove the wing from the tunnel easily. Good pictures were obtained of the flow pattern (see Fig. 19).

A complete run schedule is given in Table IV.

C. THE DATA

1. The Flow Visualization Tests

For the flow visualization, test photographs were taken of the lamp black and oil patterns on the wing and boundary layer plate. Although pictures of the top and bottom of the wing were taken for all cases, in most instances, because the wing was in the tunnel at the time, it was not possible to obtain good detailed photographs. Fig. 18 shows the pattern on the top of the flat arrow wing at 4° angle of attack and Fig. 19 that on the optimum double delta wing at its design condition.

2. Reynolds Number Tests

In many of the runs the forces were read as functions of wind tunnel stagnation pressure during the time the tunnel was being brought up to 30 psia, the pressure used for all the remaining data. For the flat wings, only the drag was read at zero angle of attack. The data for the flat arrow wing is presented in Table V and that for the flat double delta in Table VI. All this data was taken under transiet conditions while the wind tunnel pressure was changing and not all of it was reliable. Only that which was considered valid is included in Tables V and VI. The accuracy of this flat wing data is estimated to vary from about ±0.0003 in C_D at the lowest Reynolds number to ±0.0001 at the highest.

For the warped wings it was necessary to read all the data as a function of pressure. Only one set of data was obtained for each condition (trip or no trip) of each wing because of the complexity of obtaining the data. It is presented in Tables VII and VIII for the warped arrow and double delta wings, respectively. The laminar data for the warped arrow wing was obtained during Run 1, a lampblack and oil run. For this run the pressure tubing was connected and it was found that there was a zero shift in the drag data, which when corrected, reduced the drag by 15 percent at the lowest pressure and 3 percent at the highest. The data from this run should be treated circumspectly. Otherwise the accuracy of the data taken at the highest pressure should be comparable with that of the steady state data. At the lower pressures it will be reduced by at least the ratio of the pressure (or Reynolds number).

3. The Force Tests

Force data was taken with the pressure tubing both connected and cut off. The valid data is presented in Tables IX to XII for the flat and warped arrow and double delta wings, respectively. No data with the pressure tubing attached is presented for the warped wings because significant zero shifts were caused by the tubing.

Except for α_c for the flat wing and r_{cp} and α_{cp} for the warped wings the notation is standard. α_c is the angle of attack corrected so that $C_L = 0$ at $\alpha = 0$. α_{cp} and r_{cp} are the angle and radius needed to define the position

of the center of pressure of the warped wing, since it does not lie in the x, z plane.

The force data for the flat wings proved difficult to reduce. This problem was a consequence of an angular misalignment of the balance and wing axes. When it was discovered, both the wings and balance had been removed from the tunnel so that it was no longer possible to measure the angle. This misalignment manifested itself in two ways: (1) the axial force data was not symmetrical about zero lift. (2) the angle of zero lift was much more negative than usual for the wind tunnel. Once this error was discovered a correction was made by finding the angle of misalignment which made the axial force data symmetrical about zero lift, due to a lift interaction on drag. This angle was assumed constant on all the runs of each wing. Its value was .19° for the flat arrow wing and .27° for the double delta. The value given for the flat double delta is more reliable than that for the arrow because data was taken to − 6° instead of only − 2°. No problem arose in the reduction of warped wings because great care was taken to insure that the alignment of the two axes was known.

All the numbers in the tables are in computing machine format. The minus sign indicates the number is negative. The two digits to the left of the decimal point indicate where to put the decimal point (50 is for no movement) and the numbers to the right are the number itself. Thus,

$$-49.78456 = -.078456$$
$$53.56789 = +567.89$$

Although the correction to the angle of attack due to wing deflection has been computed, it was not applied here since it never exceeds .03°. The x and y of the center of pressure of the wing are given in inches from the balance centerline and wall.

The estimated accuracies of the data based on repeatability and system accuracy are:

α, α_c	$\pm$	.02°		C_x	$\pm$	.0001
α_{cp}	$\pm$	.50°	except near $C_L = 0$	C_m	$\pm$	.0001
$\left.\begin{matrix} r_{cp} \\ x_{cp} \end{matrix}\right\}$	$\pm$	.05 in.	except near $C_L = 0$	C_L	$\pm$	.001
y_{cp}	$\pm$	.25 in.	except near $C_L = 0$	C_D	$\pm$	.0001
C_z	$\pm$	.001		C_ℓ	$\pm$	.001

(Note that these estimates do not include uncertainties due to Mach number variation and flow angularities in the wind tunnel.)

4. Pressure Tests

The pressure data was recorded photographically. These photographs were then read manually, the data put on tape, and finally reduced on a G 15 Bendix computer.

The data as printed out by the computer for all four wings with appropriate labels is presented in Tables XIII through XVI. Each table contains all the data for one wing. The first thing in each table is a list of the known bad pressure taps. Then the data for each run is presented with comments concerning the difference between various runs. In each case the C_p of the top and bottom surfaces are presented as well as the difference between the two. Note that in the case of the most outboard stations the differences are for taps which are slightly displaced, as pointed out previously.

The estimated repeatability of the C_p's based on the repeat data taken at $\alpha = 2°$ in Run 6 is about $\pm.002$. Examination of a lot of data indicates an overall accuracy of about $\pm.004$ in C_p.

CHAPTER IV

THE RESULTS OF THE WIND TUNNEL TESTS

A. FLOW VISUALIZATION STUDIES

The lampblack and oil tests showed that the boundary layer splitter plate ran properly in the wind tunnel. They also brought out a number of interesting facts.

1. The flow of the lampblack and oil was slowed very greatly at the intersection of the shock wave from the junction of the wing leading edge and splitter plate. Thus the strength of this shock wave was nearly sufficient to separate the boundary layer, and in fact, may have at $\alpha = 4°$, for the flat arrow wing.

2. There is a strong scouring action at the junction of the wing and plate near the leading edge of all the wings. Usually that part of the plate and wing were swept clean of oil almost immediately.

3. The flow on the windward side of the flat wings always appears smooth (i.e., there was no indicated separation except before the gaps at the foot were reduced.)

4. For the flat arrow wing there was no leading edge separation at $\alpha = 0°$. It occurred at about 20 inches from the wing nose at $\alpha = 2°$, and at about 10 inches from the nose at $\alpha = 4°$. See Fig. 18.

5. For the flat double delta wing the results were the same except that there was no separation at $\alpha = 2°$ because of the presence of the supersonic leading edge tip.

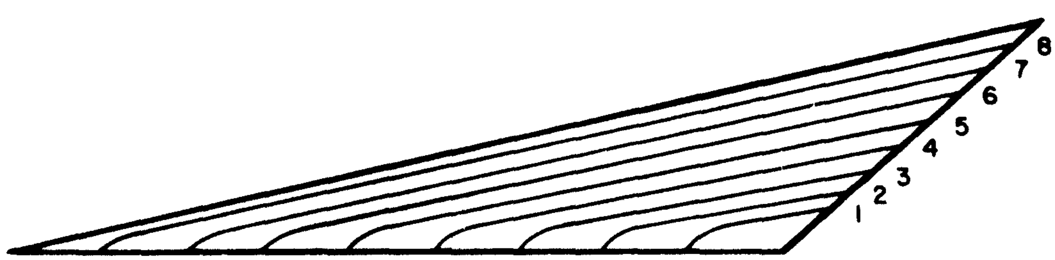
6. For the warped arrow wing the flow separated from the top surface. This separation was apparently due to the formation of a vortex above the wing. The location of the separation line on the upper wing surface created by this vortex was just downstream of the maximum height of the wing at each chordwise station (note this is not necessarily the point of maximum thickness due to the camber of the wing, see Fig. 13). There was no indication of separation on the bottom surface.

7. Figure 19 is a photograph of the oil film pattern on the top of the warped double delta wing. Note that in this case the tunnel pressure was never raised beyond about 20 psia and the flow over the tip region is

separated, whereas this does not appear to be the case at 30 psia if the pressure data is believed. On this wing the vortex separation line starts off very near the root chord and stays at roughly a constant distance back from the leading edge till it reaches the wing juncture where it then turns toward the trailing edge. There was indication of separation on the bottom of this wing, particularly near the root in the hollow.

B. REYNOLDS NUMBER EFFECTS

Some of the drag vs. Reynolds number data for the flat wings at zero angle of attack is plotted in Figs. 20 and 21. Also included on these figures are curves for a fully laminar boundary layer, and for a turbulent boundary layer over all but the first 1 or 1/2 inch of the leading edge. Both wings show the same trend, i.e., the transition from laminar to turbulent boundary layer occurs over a very large range of Reynolds numbers. This is probably due to a combination of the high sweep angle, the high taper ratio and the tendency of the wing root-splitter plate junction to cause early transition. Tentatively it is suggested that transition moves somewhat as shown in the figure below, going from 1 to 8 as the Reynolds number is increased.



It is assumed that transition first occurs at the root when Re $\cong .5 \times 10^6$ and spreads at an angle of 8° to 10° (Ref. 48) except near the trailing edge where the effect of the trailing edge shock brings on separation or early transition. Over the outboard section, the Reynolds number of transition probably is about 2×10^6 except that it will increase in the highly favorable pressure gradient near the leading edge. Thus the rate at which the line of transition moves with increasing Re probably decreases with increasing Reynolds number. The three-dimensional

character of the boundary layer is also thought to be important here.

On the flat double delta wing, because it has a somewhat smaller average sweep angle and a larger aspect ratio (i.e., the flow is more two-dimensional), the transition line should move more rapidly for the range of Reynolds numbers tested. It does.

Figure 22 is a plot of drag vs. trip height squared at the maximum pressure run in these tests. The trip height, if too large, should cause an increase in pressure drag proportional to its height squared. Thus, the straight line drawn through the 4 and 8 thickness trips should pass through the value of C_x for turbulent boundary layer with no trip drag at zero trip height. This value (see Fig. 22) agrees very well with that given by the theory in Fig. 20. Also a trip height of 3 thicknesses or .0065" appears most effective. This height agrees with that predicted using Ref. 46.

Note that the tentative explanation given above of the movement of the line of transition adequately explains the ineffectiveness of the trip. That is, a large portion of the boundary layer on the wing would be turbulent without the trip and the trip merely moves the transition from about line 6 to 8 in the sketch.

The lift drag and lift-drag ratio for the warped arrow and double delta wing are plotted as a function of Reynolds number in Figs. 23 and 24. The variations of drag with Reynolds number are somewhat less than those measured for the flat wings, but do not seem unreasonable in view of the wing camber. The lift and drag are both increased as a result of adding the trip, but the drag is increased proportionally more and the lift drag ratio decreases as one might expect. The effect of the trip on drag is greater for the double delta wing.

C. THE FORCE DATA

Plots of C_x vs. angle of attack for the flat wings are given in Fig. 25 for the two flat wings. There is only a small decrease in C_x with α for either wing. This indicates only a small amout, if any, of leading edge suction. Plots of normal force vs. angle of attack for all the wings are given in Fig. 26. The lift slopes for the flat wings are,

respectively, 7.8 percent and 6.5 percent lower than theory for the arrow and double delta wings. For the warped wing they are also nonlinear. In each case data from only one run is plotted as there is no significant change in lift with or without a boundary layer trip. This lack of change with and without a trip is another indication that the boundary layer is mostly turbulent even without a trip.

Plots of lift vs. drag are given in Fig. 27 for all four wings. Again the effect of the boundary layer trip is small and entirely due to its effect on the drag. It is interesting how closely the curves for the flat and optimum arrow wings agree above a lift coefficient of about .12.

The lift-drag ratio for all the wings including the effects of the boundary layer-trip are plotted in Fig. 28. The peak values are tabulated below.

Wing	Version	Trip	Measured L/D	Estimated L/D
Arrow	Flat	0	7.04	
"	"	4	6.76	
"	"	8	6.60	
"	Warped	0	6.60	
"	"	3	6.25	8.00
Double delta	Flat	0	6.76	
" "	"	4	6.35	
" "	Warped	0	6.54	
" "	"	3	6.26	7.00

The measured values for the warped wings are far below those estimated on the basis of the results from the flat wings and the linearized theory $\Delta C_D / C_L^2$. In fact these values are not even as good as for the flat wings. The reason for this descrepancy will be discussed in detail below in connection with the pressure data.

Plots of pitching moment vs. lift coefficient are given in Fig. 29. The pitching moment coefficient is based on the root chord of the wing and is measured about the balance axis which is at the center of the wing foot for all the wings. Note that since the warped wings are far from planar, the length obtained from dC_m / dC_L does not necessarily lie in the plane of the root chord. In fact the tabulated values in Tables XI

and XII of α_{cp} give the angle along which it is measured (α_{cp} is based on the total force on the wing).

D. THE PRESSURE DATA

The primary purpose in taking the pressure data was to enable an analysis of why the optimizing method did or did not work. The force data has shown that the warped versions of the arrow and double delta wings failed to give the lift drag ratios that were expected. Therefore the pressure data has been analyzed to try to show the why and how of this failure.

The zero lift pressure distribution of the two flat wings was found by taking the data from the top and bottom surfaces at zero angle of attack and averaging it. The averaging was necessary, since the wing was never run at exactly zero angle of attack with respect to the air stream and there is the usual small wind tunnel Mach number gradient and flow curvature[49]. Plots of the zero lift chordwise pressure distribution at the six spanwise measuring stations are presented for both flat wings in Figs. 30 and 31. Both tripped and untripped data are shown. The only significant differences in the data occur near the wing leading edge. These differences are believed to be due to local pressure perturbations caused by the trips. Much other tripped data has been examined and the trip effects shown here are typical. Note that for the arrow wing the measured pressures tend to flatten out and then rise near the outboard trailing edge. While no theoretical calculation was made for a wing with the actual thickness distribution, one was for one with a double wedge thickness distribution and as a result it is believed that no rise would be predicted for the actual wing. Thus it is thought that this rise is indicative of a marked thickening (or possibly a separation) of the boundary layer.

In this figure and all those which follow, the outboard pressures have been plotted at the nominal stations not the true slightly displaced ones.

In the next two figures (32 and 33) the $\Delta\Delta C_p = (C_{pb} - C_{pt})(\alpha = 1°) - (C_{pb} - C_{pt})(\alpha = 0°)$ has been plotted for both + and − 1° angle of attack. This particular method of plotting was chosen because it eliminates most tunnel flow angularity effects and also minimizes the effects of poorly

shaped pressure holes. The data for the arrow wing is compared with that predicted by linearized theory in Fig. 32. Except near the leading edge of the wing, the agreement between theory and experiment is good. Near the leading edge, finite thickness effects and the infinite pressures predicted by theory lead one not to expect very good agreement.

Curves have been drawn through all the experimental data in Figs. 30 to 33. Assuming that the pressure coefficients add linearly, these curves were then used to predict the pressure distribution on the top and bottom surfaces of both flat wings at 4° and 9° angle of attack. In view of the close agreement between linear theory and arrow wing results for $\Delta\Delta C_p$, it is believed these predicted results are close to what linear theory would have given. The predicted results are compared with the measured experimental pressure distribution in Figs. 34 to 37. Data from two repeat runs are included in Figs. 34 and 35.

One should bear in mind that for subsonic leading edge wings linear theory cannot be expected to give an accurate prediction of the pressure near the loading edge of the wing, because it predicts infinite pressures there. First there is the obvious limitation of a vacuum on the low pressure side. A vacuum corresponds to a pressure coefficient of $-.158$ at $M = 3$. This value of the pressure coefficient is shown on all the pressure plot figures where the predicted pressures approach or exceed it. The lowest pressure coefficient attained in the tests was about $-.13$ or about 80 percent of a vacuum.

Further, the effect of the vortex which forms above and behind the leading edge of the wing on the low pressure side is not included in linear theory. The results of this experiment tend to confirm the fact that at small angles of attack the effect of the vortex is small where as at large angles it can alter the pressure distribution over nearly the whole wing.

For instance, the predicted and measured pressures near the root for both wings are in good agreement at $\alpha = 4°$ (Figs. 34 and 35). Near the leading edge at the three most outboard stations of the arrow wing and at the last outboard station of the subsonic leading edge section of the double delta wing the agreement becomes poor.

Again at $\alpha = 9°$ for the flat arrow wing the agreement between the predicted and measured pressure is still reasonable at the inboard stations except right at the leading edge. In fact, apparently because of the vortex on the top of the wing, the total lift at stations $y/b = .25$ and $.40$ is somewhat higher than is predicted. However at the two most outboard stations, the agreement is poor and at the last station the total lift must be down 50 percent.

Over the subsonic portion of the flat double delta wing at $\alpha = 9°$ the results are similar to those on the arrow wing, but over the supersonic leading edge section, while there is a loss of lift, it is restricted to the top or low pressure side of the wing.

An interesting feature of the flat wing data is that behind a subsonic leading edge, whenever the upper surface pressure fails to approach the predicted value, both the upper and lower surfaces seem to be limited by this failure on the upper surface, or vice versa. That is, if the peak negative C_p on the top surface is $-.10$ then the peak positive pressure on the lower surface is also about $+.10$. Thus at least 50% of the loss in lift can be attributed to the bottom surface.

The supersonic leading edge tip of the double delta wing does not show any loss of lift on the bottom surface; in fact, the predicted and experimental pressure are in very close agreement even at 9°. The last outboard spanwise station for this part of the wing is beyond the influence of the wing crank and so except for thickness effect and the fact the flow is still influenced by the subsonic leading edge the flow would be two dimensional.

Linearized theory normally works well in a two dimensional region because, while on the lee side of the wing, the predicted low pressures are not attained, there is an excess of pressure on the windward side which makes up for the loss on the lee side. This situation is illustrated in Fig. 38, where the C_p vs. angular flow deflection according to linear theory is compared with Prandtl-Meyer expansion and oblique shock theory for a 60° swept leading edge at $M = 3$. For a compression the flow becomes sonic at an angle of about 6.0°. Thus, the oblique shock curve has not been calculated beyond 6° on the compression side of the wing, but it is clear

that one would expect the measured pressures to be higher than those predicted.

The results shown in Fig. 38 have been used to correct the predicted pressures at the most outboard station on the lee side of the double delta wing. However, before this was done a calculation was made to determine how much both wings deflected. To accomplish this, loads were hung at seven stations on each of the flat wings and the change in angle of attack measured at all stations. Thus a structural matrix relating change in angle of attack to load was found for each wing. Note the measurements were made with the wing mounted in the wind tunnel and thus include both balance and wing deflections. These matrices for the flat version of each wing are given in Tables XVII and XVIII. They are not symmetrical because they relate angle, not deflection, to load.

The calculated deflections for the measured load distribution at $\alpha = 9°$ are also given in the tables. The worst deflections occur at the wing tip stations. They are about $-.5°$ and $-1.0°$ respectively for the flat arrow and double delta wings. Similar calculations were also made using the above matrices and the load distributions obtained on the optimum wings at $\alpha = 0°$. The deflections were again greatest at the tips, but were only about 1/2 those given above. Actually the optimized wings were probably somewhat stiffer than the flat ones and the above deflections are overly large.

Using the above deflection data, the pressure distribution for the most outboard station on the double delta wing was recalculated assuming $\alpha = 8°$. Then a correction due to the nonlinear relationship between deflection angle and pressure shown in Fig. 38 was applied to the prediction for the expansion side (see Fig. 37). The close agreement between this prediction and the data indicates that the flow over the upper surface is attached.

Finally a calculation was made of the pressure distribution over a flat two-dimensional wing using linearized theory and the measured pressure distribution due to thickness. This result is also shown in Fig. 37. The difference between this result and the predicted result for 8° shows the effect of the upwash created by the subsonic nose of the wing. Note that as expected the upwash increases the lift and therefore has a favorable effect on the drag-due-to-lift.

The warped wings were designed to have zero loading at the leading edge and the particular designs used were chosen for there reasonable peak pressures and pressure gradients. By this means it was hoped to avoid the formation of the leading edge vortex or at least to minimize its effect. In both cases the restrictions put on the peak positive and negative pressures and pressure gradients were not sufficiently severe and a leading edge vortex did form. Also on both warped wings serious boundary layer separations apparently contributed to the difference between measured and predicted pressures.

The measured pressure difference between the top and bottom surfaces of the warped arrow and double delta wings are compared with that predicted by linear theory in Figs. 39 and 40. As in the case of the flat arrow wing at 9° the agreement between the theory and experiment is worst near the tip of the warped arrow wing. However for the warped double delta the worst disagreement is at the root station.

The chordwise data given in Fig. 39 and 40 has been integrated to obtain the experimental and predicted spanwise loading of the two optimum wings ($\overline{C}_p\ c/c_0$). These have been plotted vs. the normalized spanwise variable in Fig. 41a and b. From these plots it is apparent that the loss in lift is more or less uniform along the span of the arrow wings, whereas most of the loss occurs near the root chord of the double delta wing.

In the next two plots (Figs. 42 and 43) the experimentally measured pressures on the top and bottom of the optimum arrow wing at $\alpha = 0°$ and 0.5° are compared with that predicted by adding or subtracting one half the theoretical optimum load distribution to measured pressure distribution due to thickness as shown in Fig. 30. At $\alpha = 0°$ there is a difference between predicted and measured pressures on the upper surface even at $y/b = .1$ ($x/c = .3$). From $y/b = .25$ to the tip the flow is apparently always separated in the hollow under the wing. Again a great loss of lift near the tip is evident. At $\alpha = 0.5°$ the results are similar, but the small angle of attack has caused a slight peak in the positive pressure near the leading edge of the wing.

So for this wing, the disparity between measured and predicted pressures is probably due to a combination of the formation of the leading edge vortex and the separation in the hollow under the wing.

A similar comparison is made for the warped double delta wing at $\alpha = 0°$ in Fig. 44. Data both with and without the boundary layer trip are shown on this plot. Again the only significant difference between the tripped and untripped data occurs near the leading edge. This plot shows that the loss in lift over the subsonic part of the wing (as in the case of the flat double delta wing) is just as great or greater on high pressure surfaces as on the low pressure surface. However on this wing the greatest loss of lift appears to be due to a break down of the flow at the wing root. The pressure gradients near the leading edge on the wing are somewhat greater than those on the arrow wing and are thought to be the source of the problem.

The wing deflection calculations indicated that the warped double delta wing had a negative twist of .4 degrees at the outboard station for the measured load distribution at $\alpha = 0°$. Therefore a second predicted curve has been included in Fig. 44 to show the effect of this negative twist at the most outboard station. Also the new predicted curve has been corrected for the nonlinear variation of pressure with angle using Fig. 38. The results seem to show that the flow is not separated on the lee surface and that there is more upwash than expected near the wing leading edge.

The next figures show the effect of changing the angle of attack +5° from the design point. The results for the subsonic leading edge parts of the warped wings are pressure limited in the same way the flat ones were, (i.e., the positive and negative pressure coefficients never get above .1). Again the supersonic leading edge portion of the double delta wing is in good agreement with the prediction except on the low pressure surfaces.

It appears then that the restrictions imposed in designing the warped wing models (see page 22) were incorrect, and excessive pressure gradients were allowed. A more nearly constant pressure distribution is necessary and, in addition, the criterion for <u>small</u> perturbation velocities possibly should be the same for all of the velocity components, i.e., $|w|_{max} = |u|_{max}$. (For the present design, values of $|w|_{max}$ approximately twice $|u|_{max}$ were permitted. A reliable limit for $|u|_{max}$ is known, of course, by the physical limitation that negative pressures cannot exceed in magnitude 75 to 80 percent of vacuum). These two limitations (smaller pressure gradients, $|w|_{max} \approx |u|_{max}$) imposed together would dictate that it is not possible to camber the wing to achieve the total lift coefficient needed for cruise

($C_{L_{cruise}} = 0.1$), but one must design for less that this, $C_{L_{design}} < C_{L_{cruise}}$, and obtain the additional lift by angulating the wing to higher incidence. An additional drag penalty must be accepted, of course, even in theory, since the wing would be operating at off-design condition, but improved wind tunnel performance might be expected.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL COMMENTS

The lack of success of the wind tunnel tests to achieve the predicted good lift-drag ratios is most probably the result of a failure to establish properly limited pressure distributions on which to base the design of the model. Although it was recognized that the problem was essentially one of viscous effects (and not a second-order potential flow problem involving thickness-camber interaction, as was originally supposed) the order of magnitude of the effort needed to solve the viscous problem was beyond the scope of this study. Indeed, the difficulty of establishing a sufficiently accurate calculation method enabling the linear-theory design of low-drag wings having arbitrarily limited pressure distribution was underestimated. The solution presented here was achieved, finally, by the numerical procedure of Mr. Roy Krupp outlined in Appendix II.

Krupp's method permits the drag and wing shape according to linearized theory to be calculated accurately for arrow and double-delta wings supporting any load distribution (at least, any that seem of interest). The types of pressure loadings desired are, of course, those which would ensure wholly attached flow over the wings. Since criteria for ensuring attached flow were not known, there were substituted instead, the criteria of small perturbation velocities (everywhere) and smooth gently-varied pressure distributions. Unfortunately, the peak positive and negative pressures and pressure gradients, particularly the spanwise gradients, were excessive and the flow separated on both the upper and lower wing surfaces, giving very high drag and consequent low lift-drag ratios. (The apparent lower surface separation on the arrow wing probably could have been predicted had there been sufficient time to check for it before fixing the model design.)

B. THE VALIDITY OF THE BASIC APPROACH

In spite of the failure to achieve good lift drag ratios, it is believed that the design philosophy is essentially correct. That is, linear theory probably provides a useful and adequate design method, provided its basic assumptions (of small perturbation velocities) are enforced everywhere on the planform. In addition, it is necessary to restrict the pressure distributions so that the assumed flow is a physically possible one. In any case, it would appear that the most urgent requirement is a fresh examination of the problem of determining the necessary and sufficient conditions for avoiding separation, forward of the trailing edge, on highly swept wing planforms. In this connection, the results of Carlsons' and the current experiments illustrate, for the angle of attack and Reynolds number range of the two experiments, these significant limitations:

(a) When separation or departure from linearized potential flow occurs, the pressures on both the top and bottom surfaces are affected and the departure occurs at approximately the same magnitude of positive and negative pressures.

(b) Initial breakdown of the flow occurs at a magnitude 20 to 30% of the C_p of vacuum.

(c) Comparing the data from the optimum arrow and double delta wings, the seriousness of the separation (or breakdown of the flow) is apparently very dependent on the spanwise pressure gradients. Near the root of the double delta wing dp/dx is larger and so is dp/dy (in both positive and negative magnitudes) than for the arrow wing and the loss in lift is increased from 20 to 50%). Also, the pressure gradients are larger at the outboard stations of the arrow wing where the percent loss in lift is greater. There is probably a scaling effect here, i.e., for higher Reynolds number (and fully turbulent boundary layer) higher pressure gradients will be required to separate the flow.

C. VISCOUS EFFECTS AND THICKNESS DISTRIBUTION

A primary conclusion is that, because of the necessity of designing to avoid viscous effects, the thickness and loading problems cannot be separated. The interaction of thickness pressures with lifting pressures

as it affects the design of low-drag cambered wings, is not a second order effect as is frequently stated, but is first order in that it is the sum of the two (lifting pressure plus thickness pressure) which determines the boundary layer characteristics. Thus the design of the thickness distribution should not be undertaken independently (see Ref. 51). [This means, practically, that the numerical procedures should be extended to include the calculation of pressure and drag due to thickness. This had to be omitted in the present study because of time limitation. It is not a major extension of the numerical procedures of Appendix II. A correction to linear theory would be necessary, in most cases, near the nose region; this probably could be approximated from the work of Van Dyke.[45]]

D. VISCOUS EFFECTS AND THE DESIGN LIFT COEFFICIENT

It is probable that the inclusion of the proper criteria on the peak pressures and pressure gradients will dictate a design lift coefficient less than that required for cruise, so that the maximum lift-drag ratio will be obtained with some additional incidence. However, if the additional lift required above the design value is large, it may be that while some gain in lift-drag ratio can be made, a greater one could be had if the effect of the leading edge vortex could be included in the theoretical solution (surely in this case there will be a strong leading edge vortex). The trouble is that the problem of predicting the location and strength of these leading edge vortices is formidable, and once they are added, the whole problem is no longer a linear one.

Because of the great difficulty of including the vortices in the analysis, and the success of Carlson[26] and Mc Lean and Fuller[50] in obtaining improved lift-drag ratios using similar techniques (even though they did not get all the improvement that linear theory predicts), it is believed that the use of linearized theory still offers the best chance of obtaining reasonable increases in the maximum lift-drag ratio of wings in the near future.

E. OTHER EFFECTS OF VISCOSITY

The inclusion of adequate criteria to control the development of

the viscous flow will probably influence the design of the wing planform. In particular, for the arrow planform it is not unlikely that the sharply pointed tips may be inappropriate, because of the large pressure gradients predicted in that region by the theory.

The experimental work reported by Mc Lean and Fuller[50] indicates that blunting the airfoil leading edge has an unfavorable effect on the maximum obtainable lift-drag ratio. It is believed that the blunting moves the vortex aft on the wing, thus reducing the favorable upwash at the leading edge of the wing. In the current experiment the warping used on the arrow wing seems to have had just this effect (i.e., it has acted in the same way blunting the leading edge would have). In any case it would seem advisable to use a sharp leading edge on any future tests.

F. A FURTHER COMMENT ON THE THICKNESS DISTRIBUTION

In considering the design of suitable thickness distributions for low-drag wings, it would be of interest to investigate whether there are reliable methods for estimating the base drag of three-dimensional swept wings for the blunt trailing edge case. It is possible that some blunting of the trailing edge might be useful to alleviate the boundary layer separation problem as well as to relieve the structural problem inherent in these aerodynamically-desirable thin wings. The total pressure drag of the wing would have to be checked, of course, but this would be a routine matter once numerical procedures for computing thickness drag, as suggested previously, were available.

G. SOME RECENTLY DISCOVERED MATERIAL

Some of the excellent British research on the problem of designing cambered wings with controlled viscous flow has, belatedly, come to light (inexplicably, this was not located in earlier searches). Though the British analyses are carried out largely within the framework of the slender-wing approximation of aerodynamic theory, their conclusions are applicable on a broader scale. Their criteria for pressure gradients favorable to the development of attached flow appear useful and could be applied within the framework of linearized theory, using the calculation methods developed for this program. A partial list of

pertinent references has been included[51-53].

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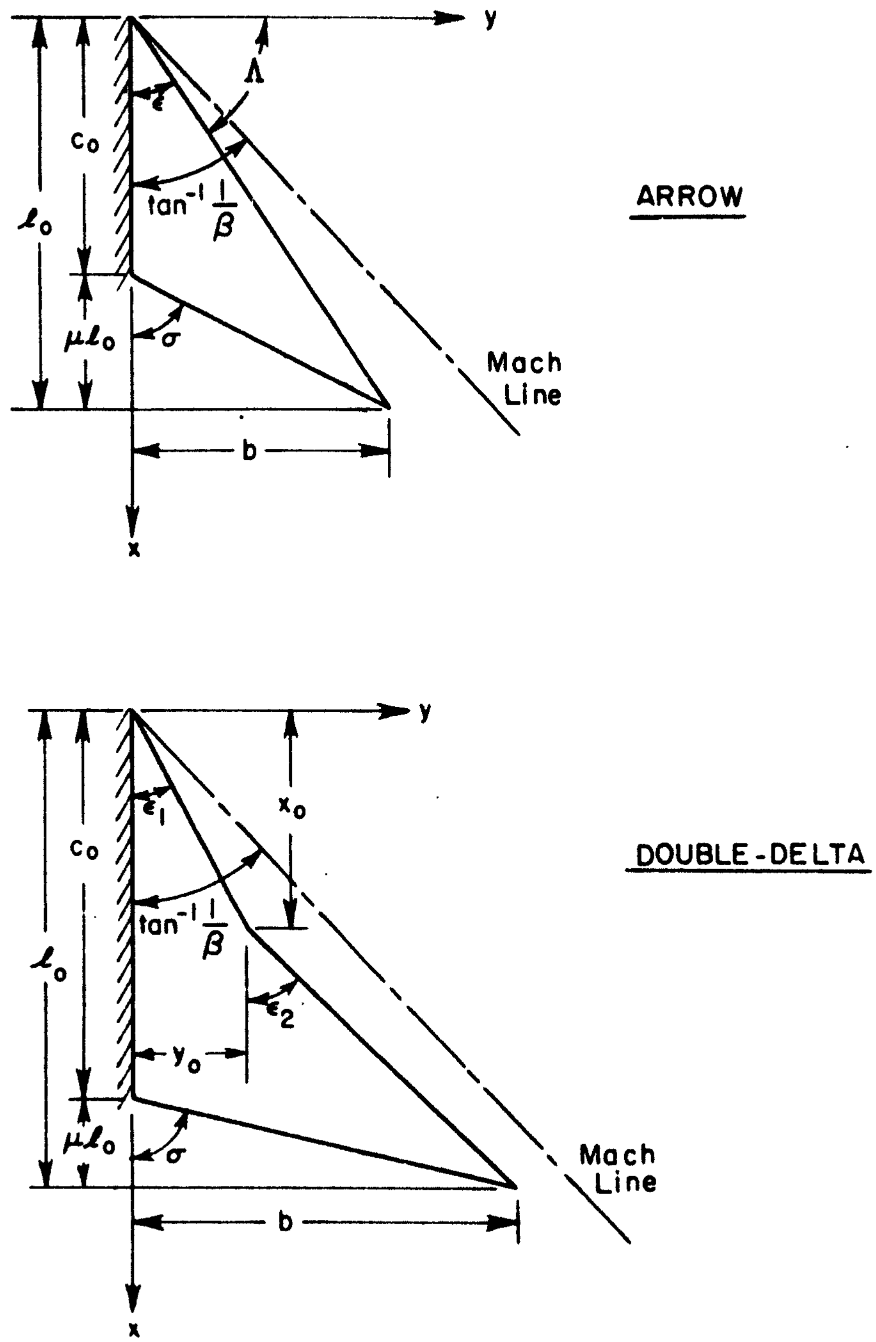


Figure 1. Sketch of planforms, showing notation and coordinate systems

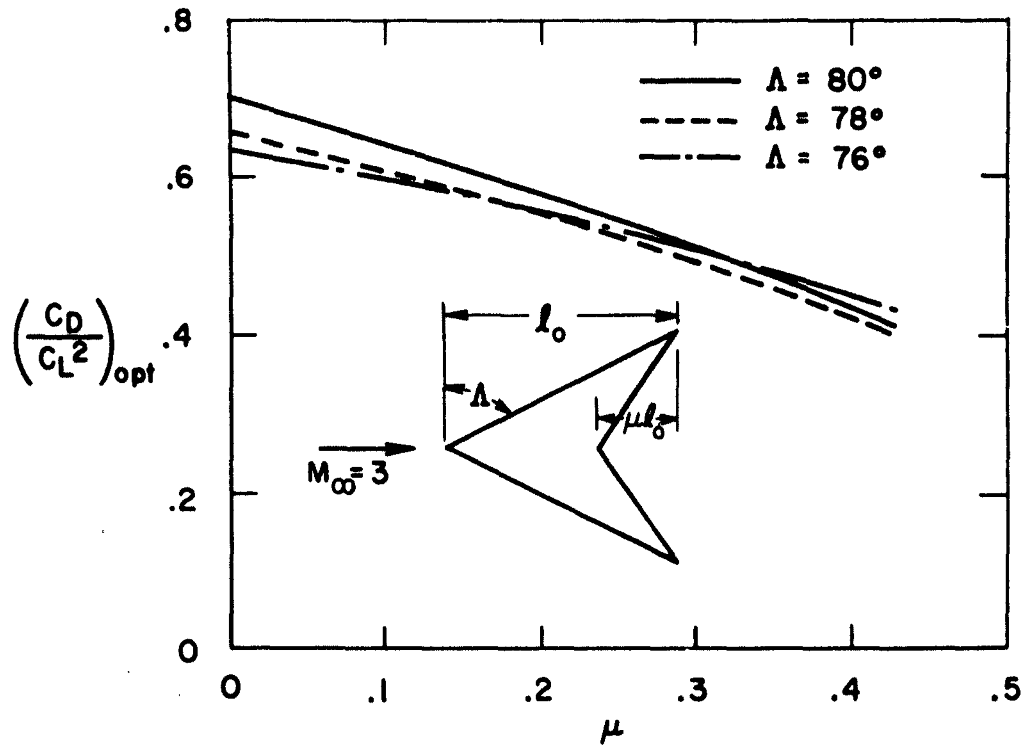


Figure 2. Variation of minimum drag rise factor with trailing-edge sweep for arrow wing at Mach number 3

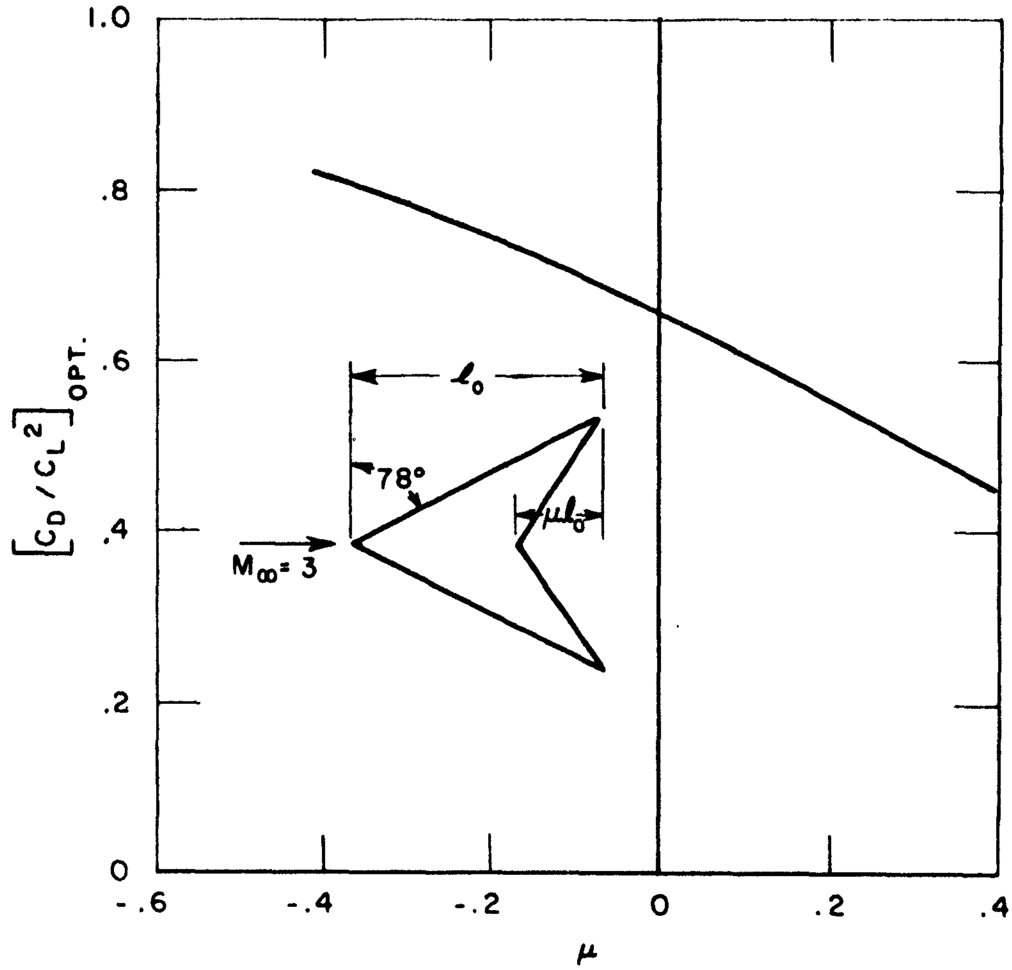


Figure 3. Variation of minimum drag rise factor with trailing-edge sweep for 78° swept arrow wing at Mach number 3

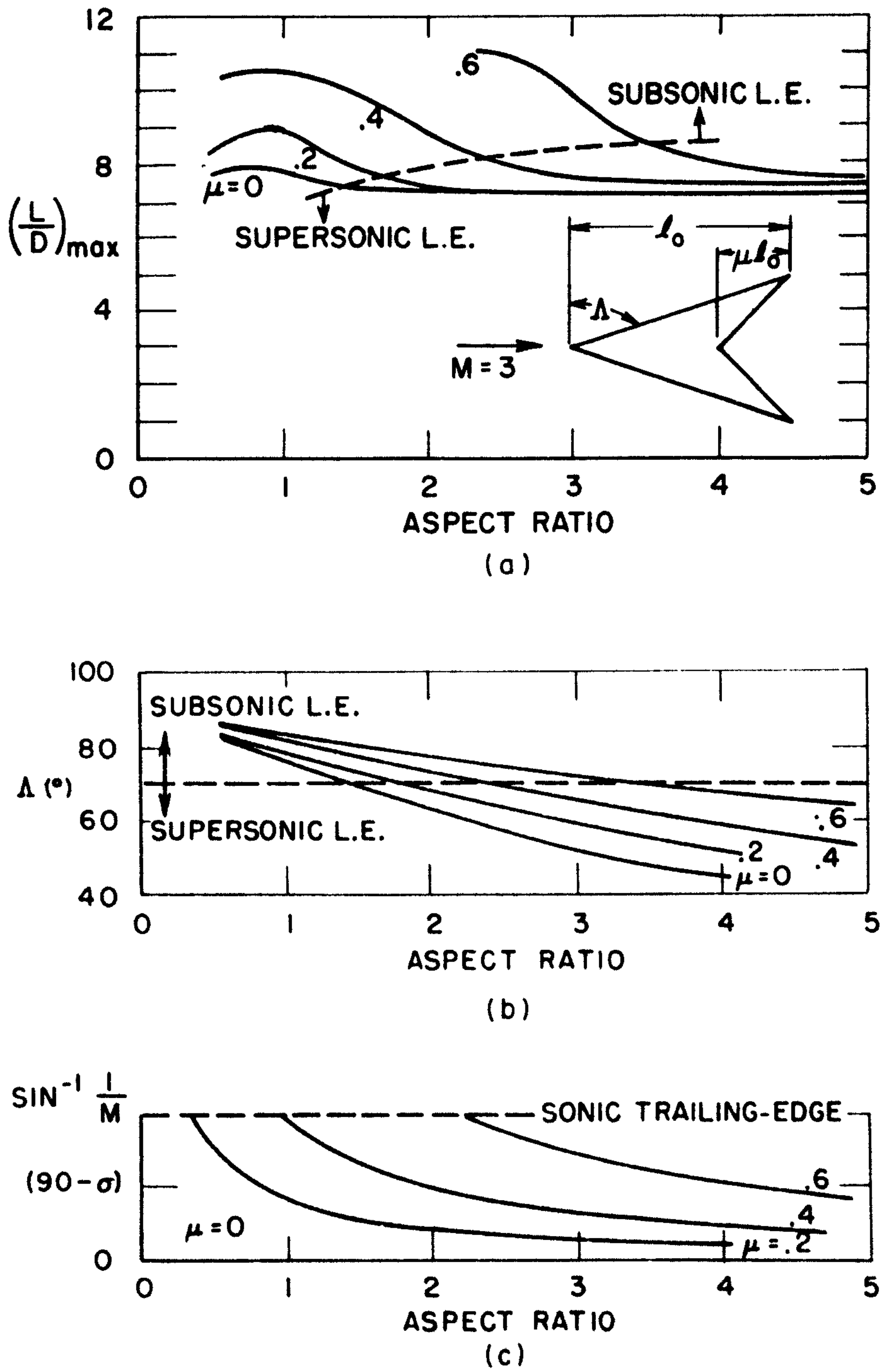


Figure 4. Maximum L/D for 3 per cent thick arrow wings at Mach number 3

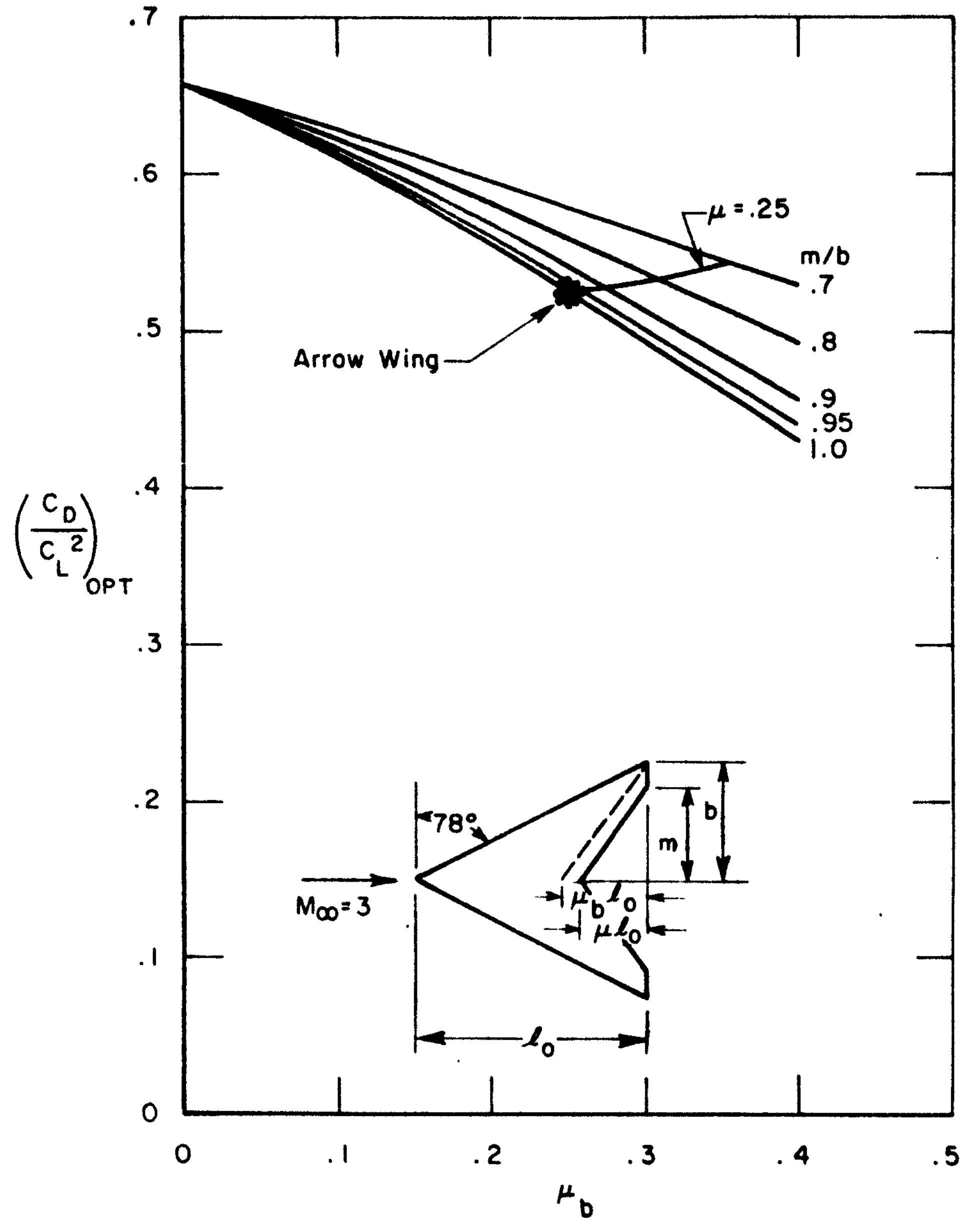


Figure 5. Variation of minimum drag rise factor for arrow wings with cut off tips at Mach number 3

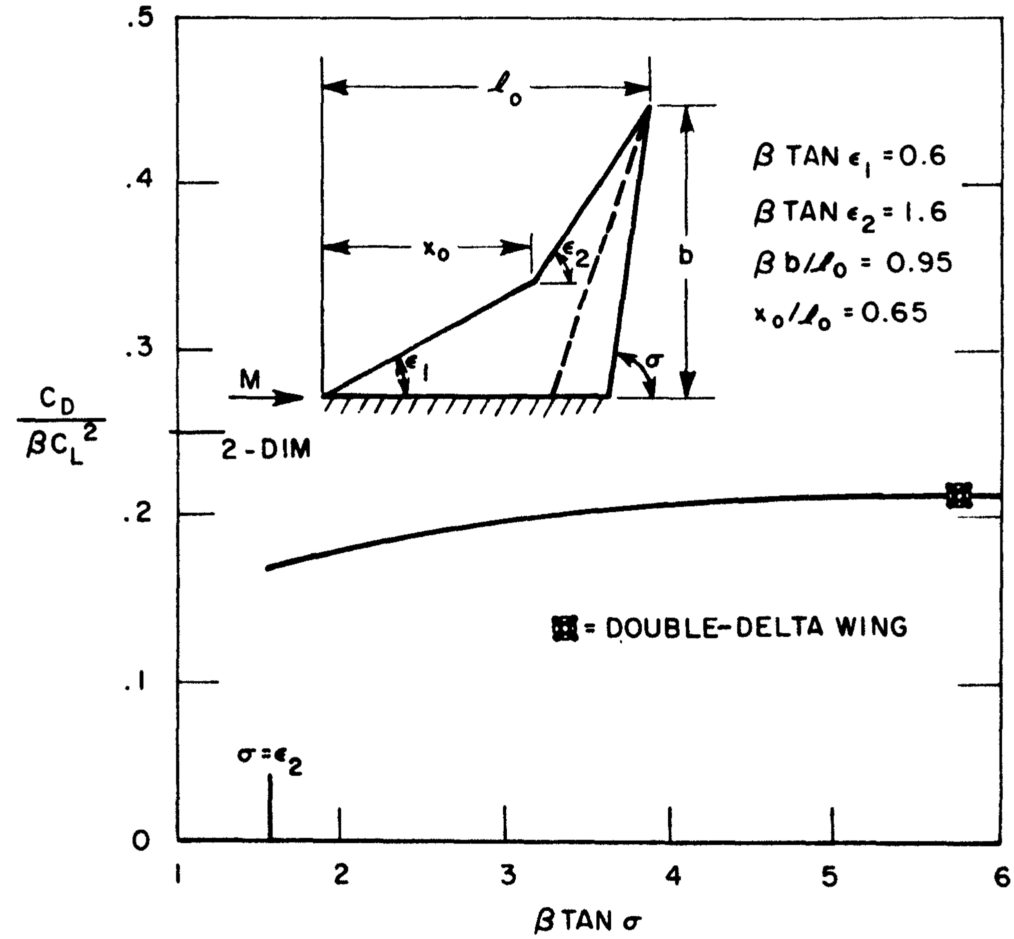


Figure 6. Variation of minimum drag rise factor with trailing-edge sweep for the double-delta wing; leading edge geometry fixed

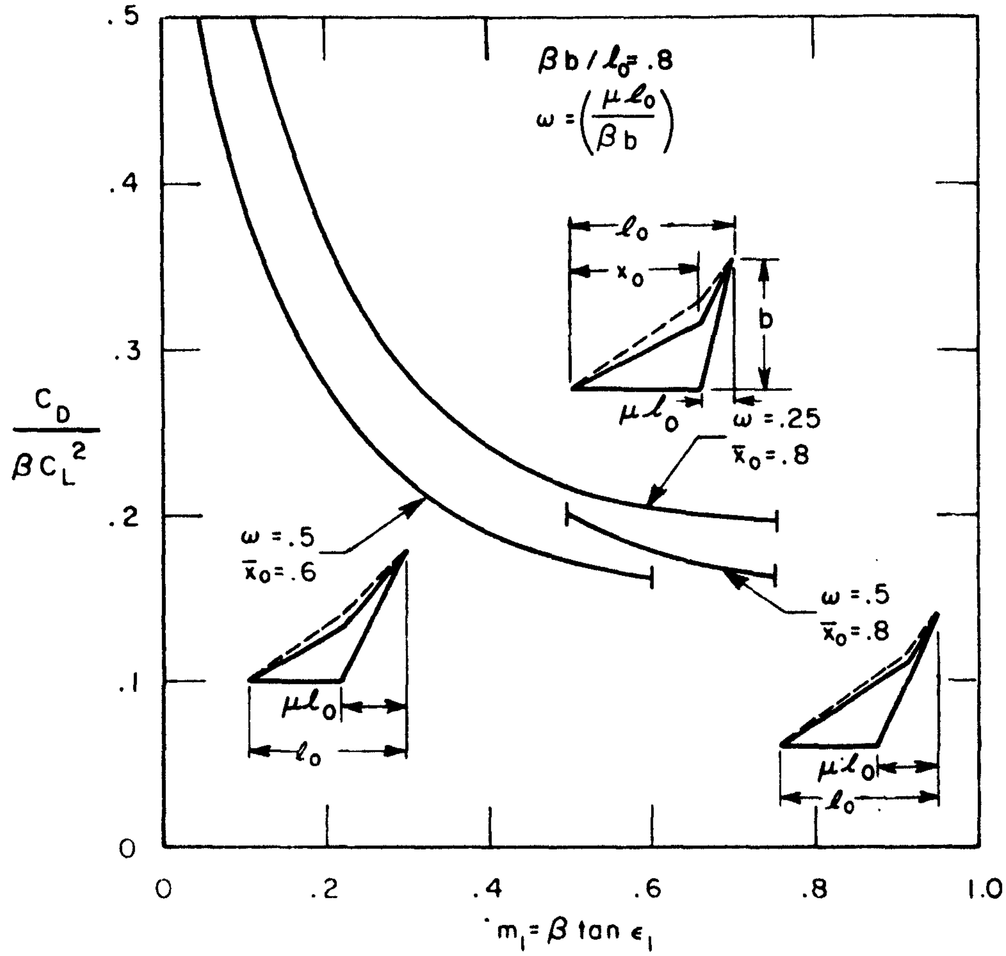


Figure 7. Variation of minimum drag rise factor with leading edge sweep; x_0, b, μ fixed

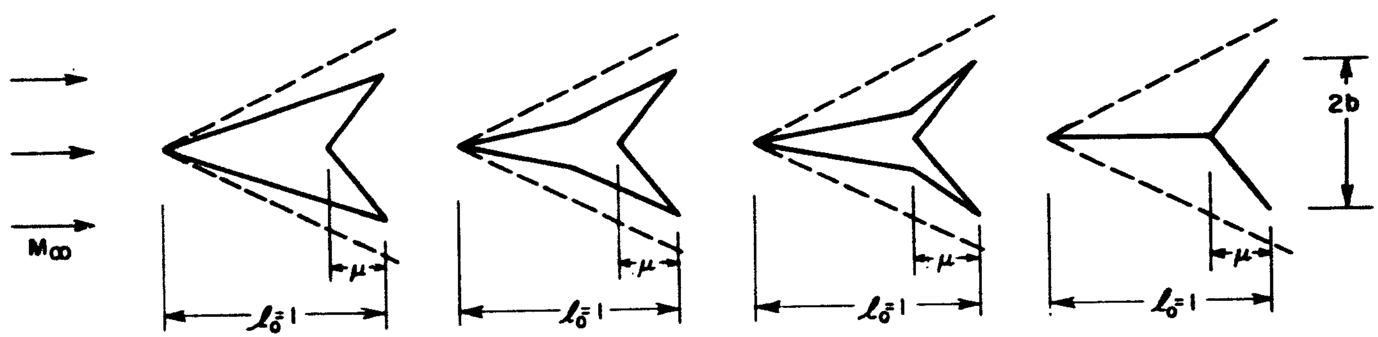


Figure 8. Family of wings having same minimum drag due to lift

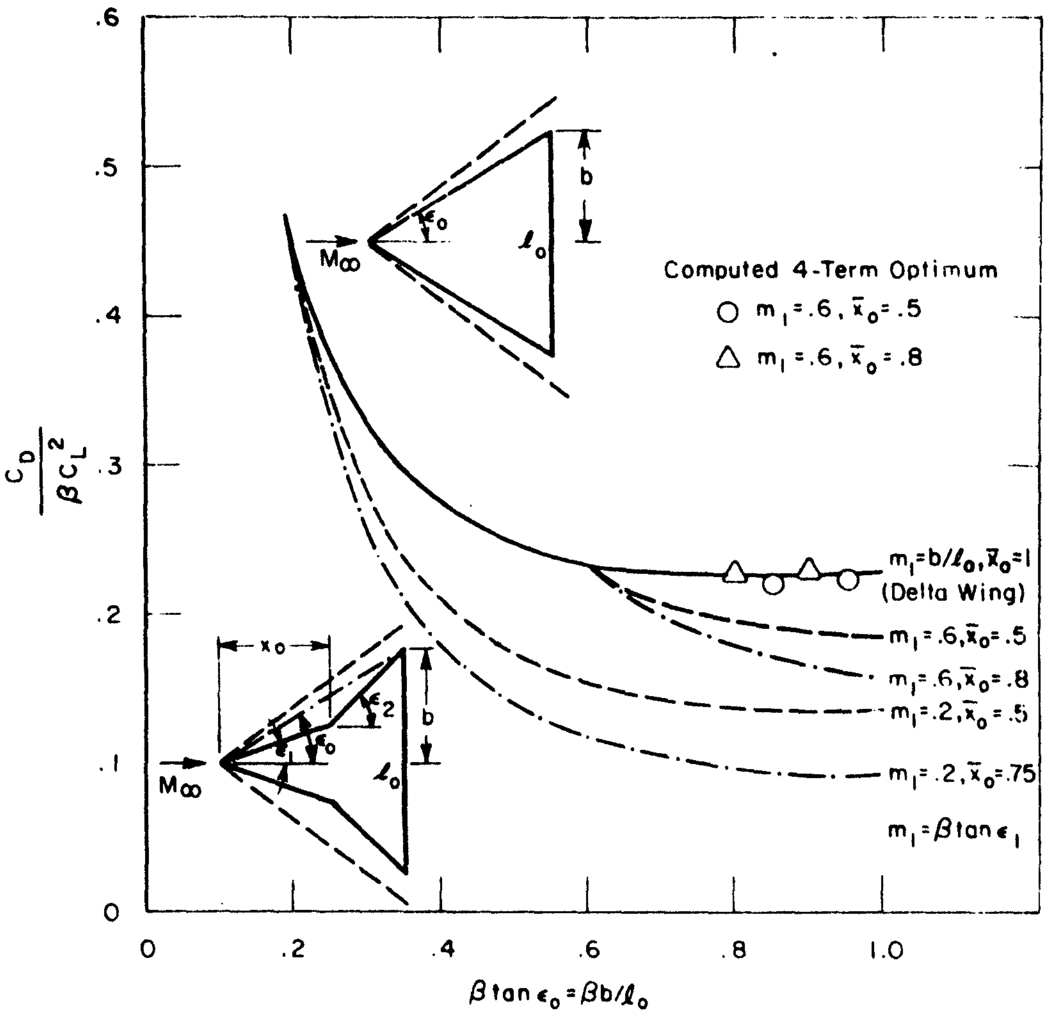


Figure 9. Some minimum drag solutions computed from delta wing solution by area ratio method, and comparison with some computed optimum four term polynomial solutions

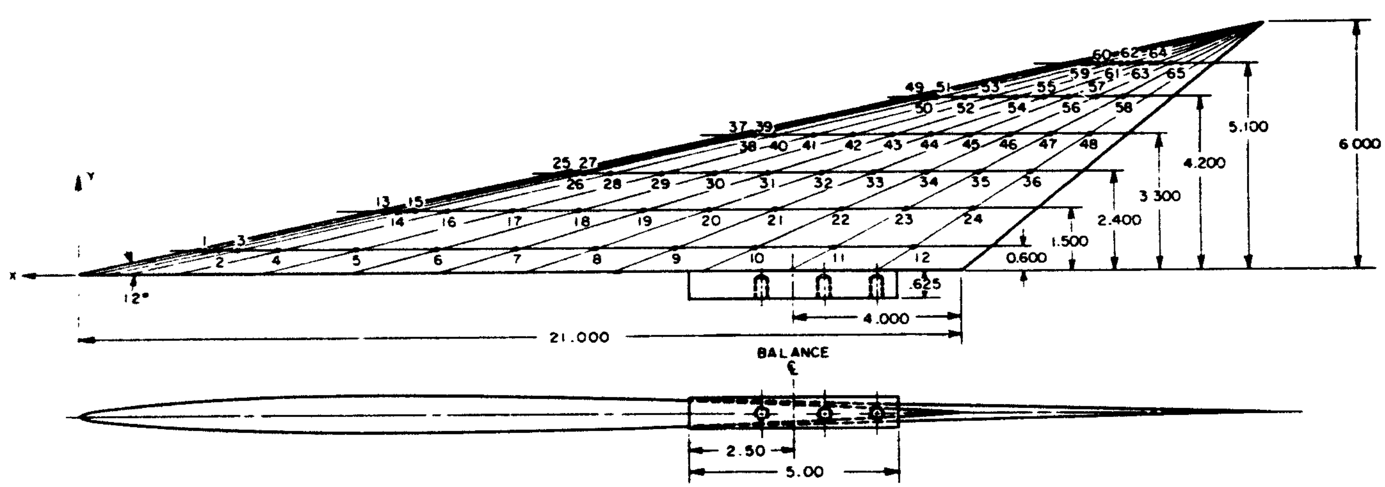


Figure 10. Drawing of arrow wing showing pressure tap locations

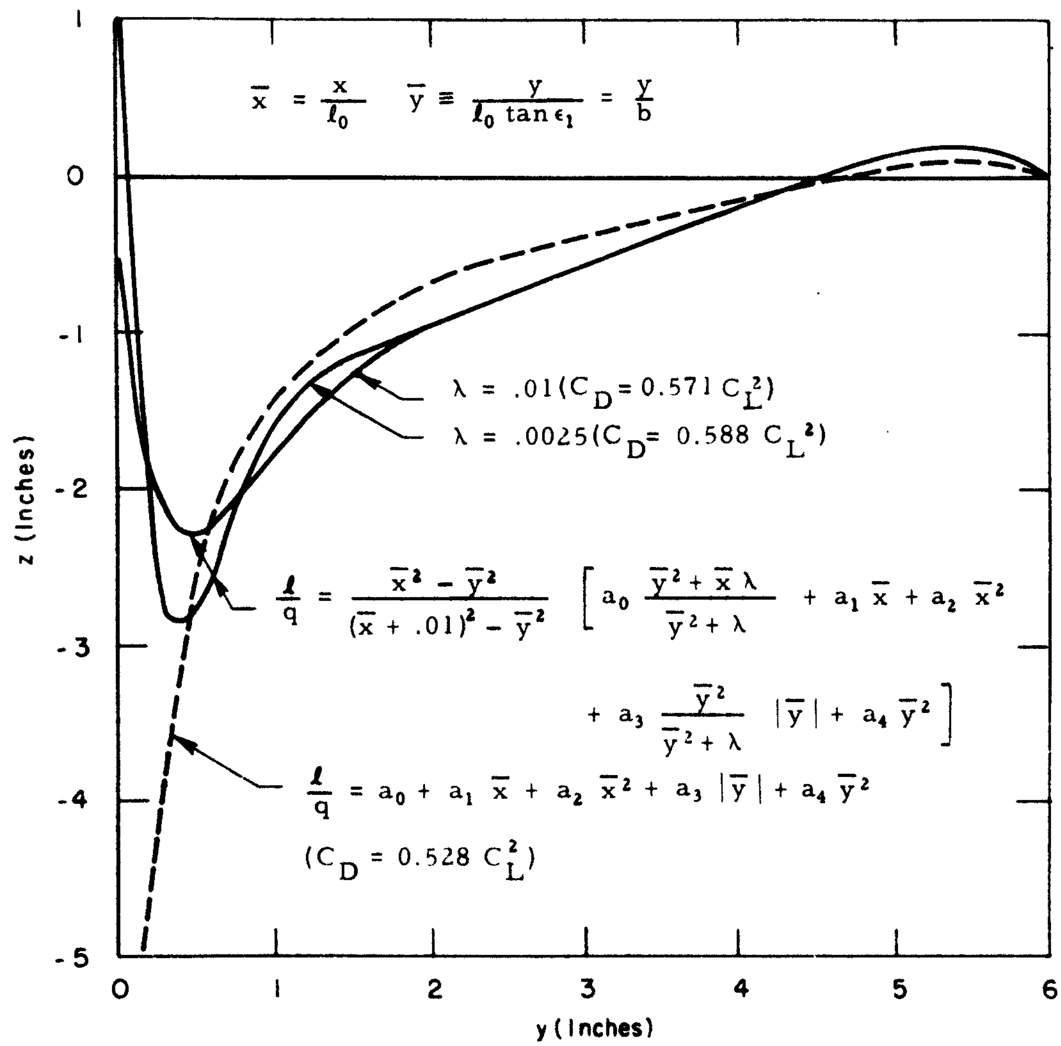


Figure 11a. Trailing-edge ordinates for various loadings on arrow wind tunnel model planform

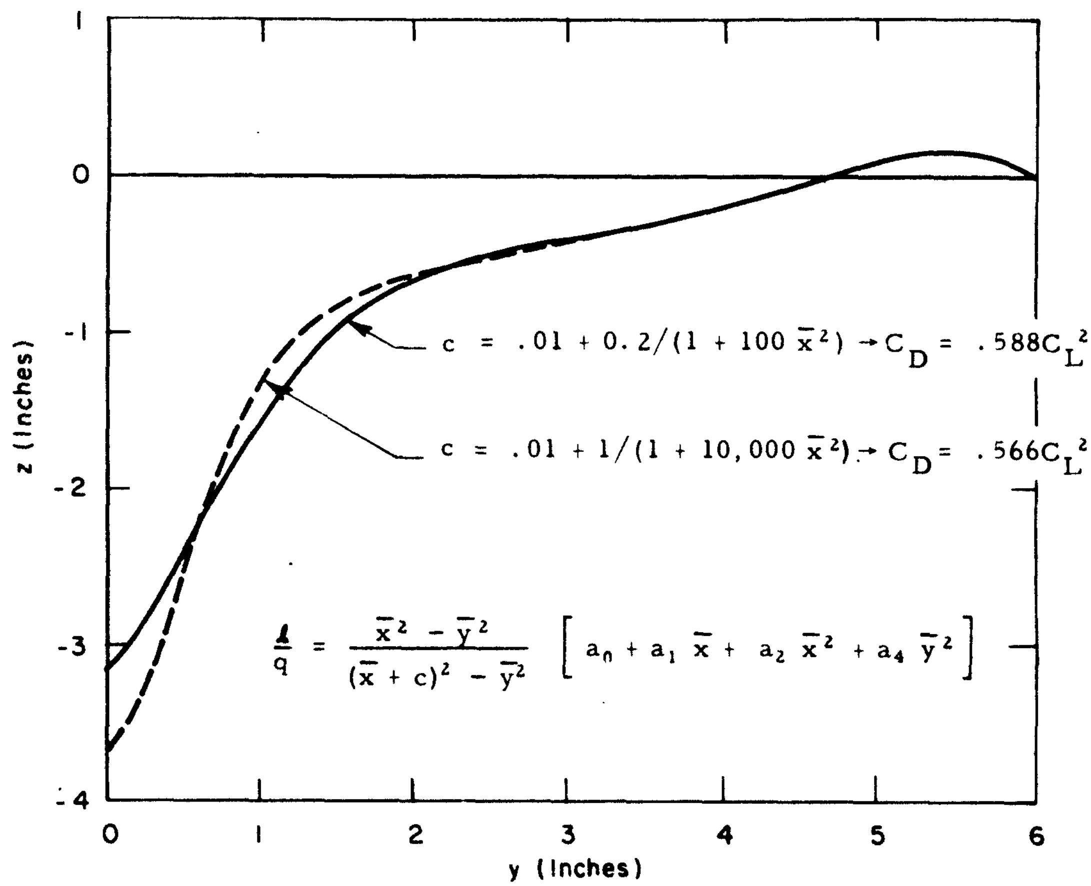


Figure 11b. Trailing-edge ordinates for various loadings on arrow wind tunnel model planform

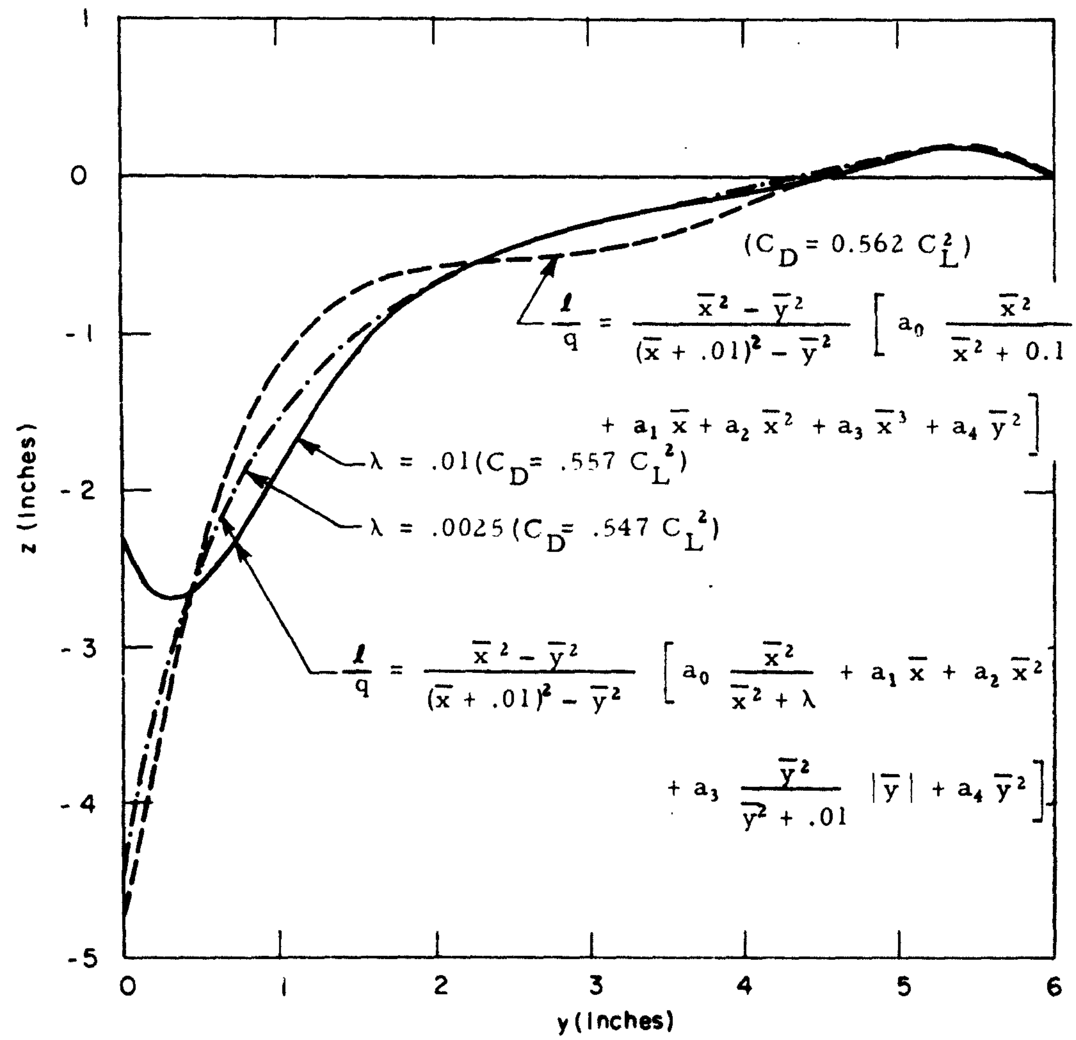


Figure 11c. Trailing-edge ordinates for various loadings on arrow wind tunnel model planform

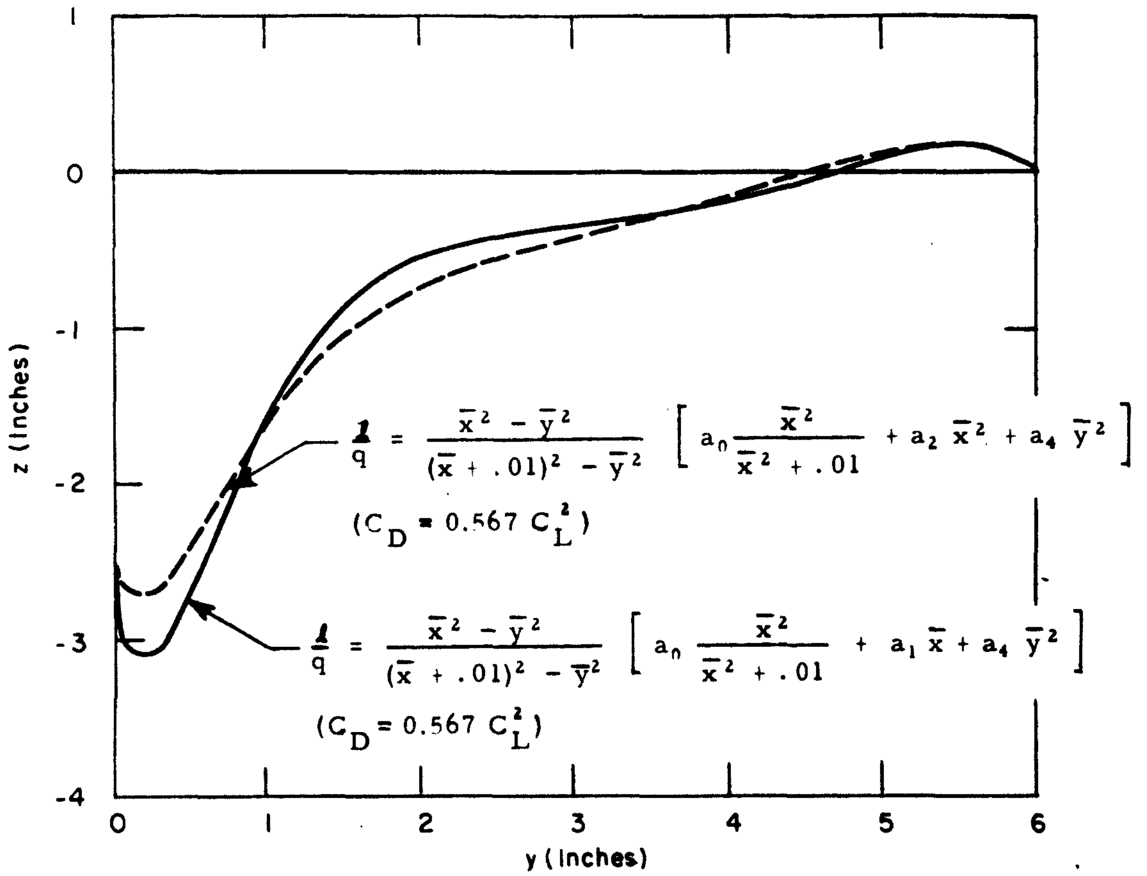


Figure 11d. Trailing-edge ordinates for various loadings on arrow wind tunnel model planform

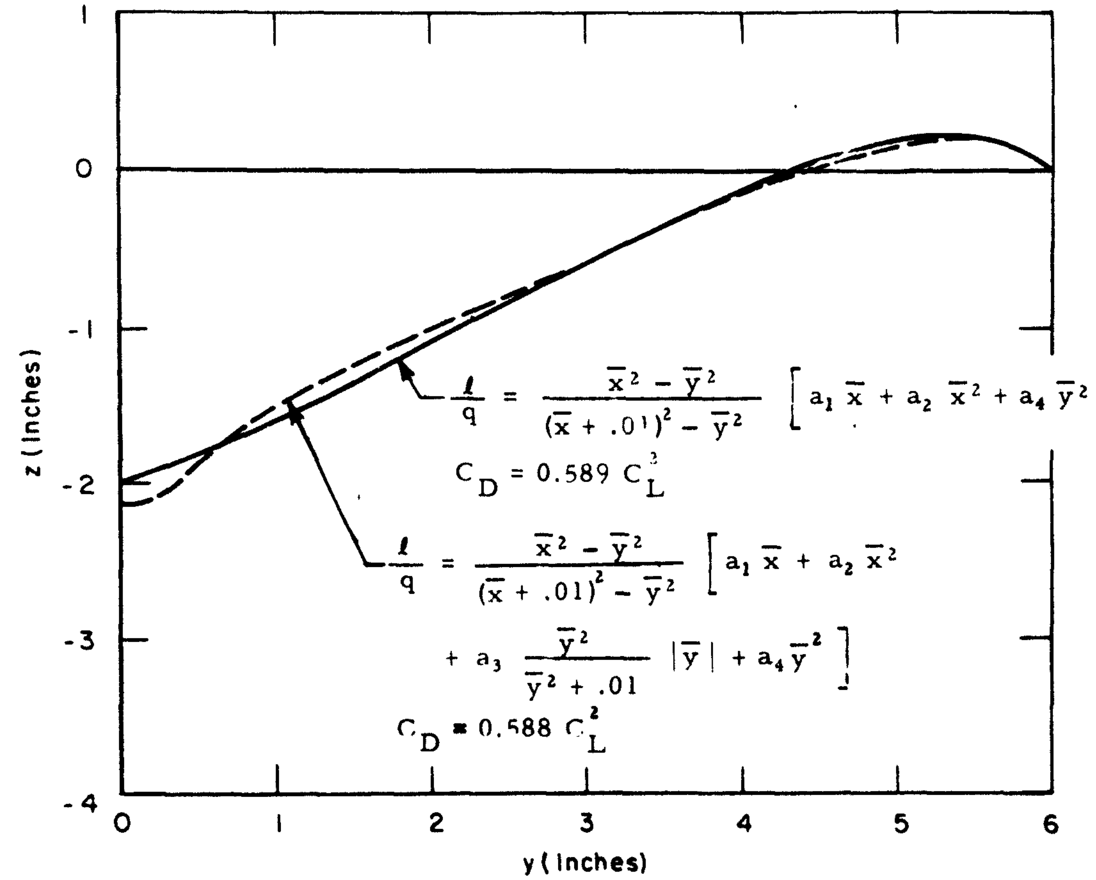


Figure 11e. Trailing-edge ordinates for various loadings on arrow wind tunnel model planform

$$\text{STANDARD} \quad \frac{\ell}{q} = a_0 + a_1\,\bar{x} + a_2\,\bar{x}^2 + a_3\,|\bar{y}| + a_4\,\bar{y}^2$$

$$\text{DESIGN} \quad \frac{\ell}{q} = \frac{\bar{x}^2 - \bar{y}^2}{(\bar{x} + .01)^2 - \bar{y}^2}\left[a_1\,\bar{x} + a_2\,\bar{x}^2 + a_4\,\bar{y}^2\right]$$

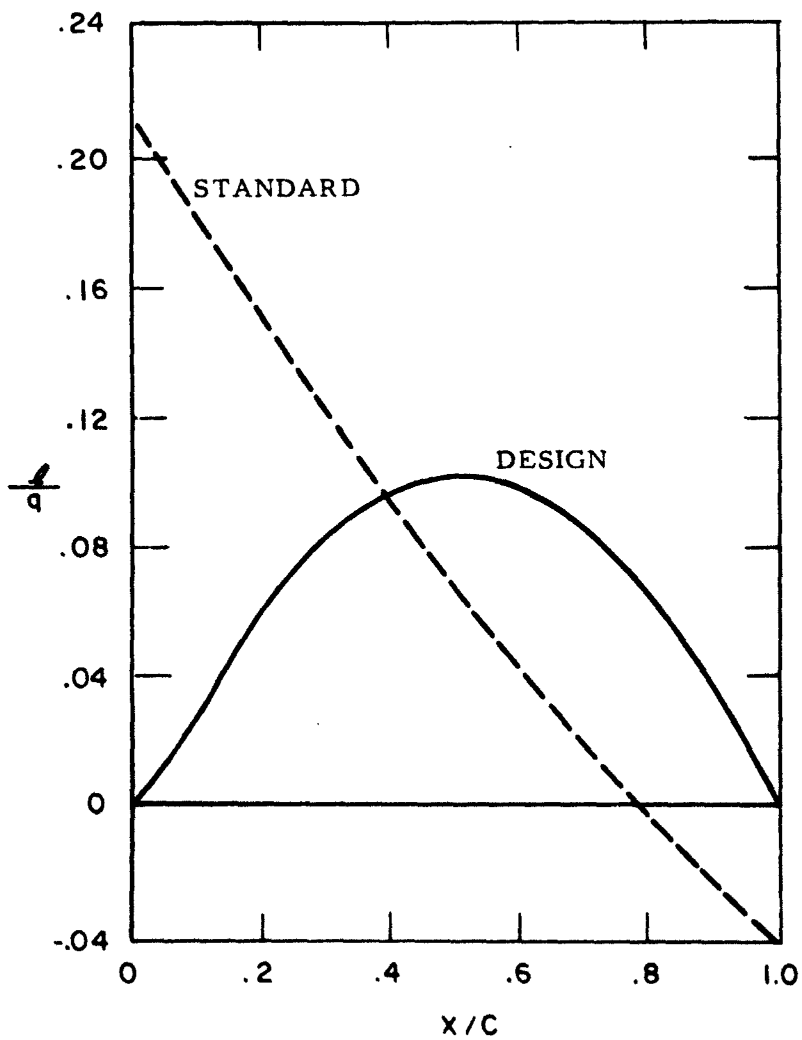


Figure 12a. Warped arrow wing chordwise loading at $\frac{y}{b} = 0$.

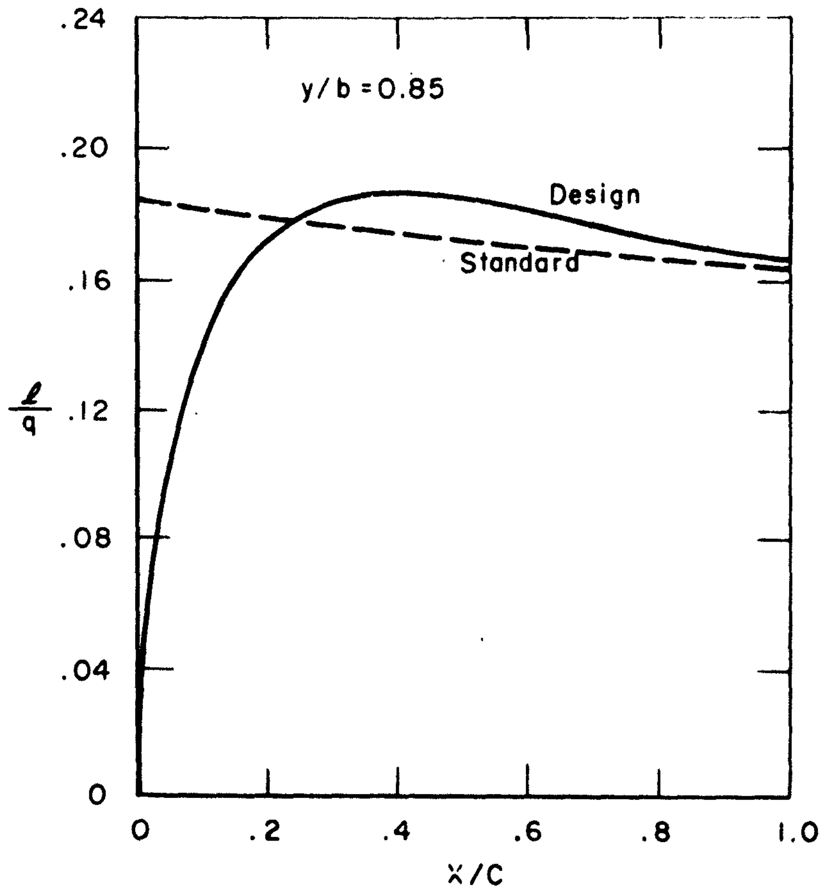


Figure 12b. Warped arrow wing chordwise loading at $\frac{y}{b}$ = 0.85

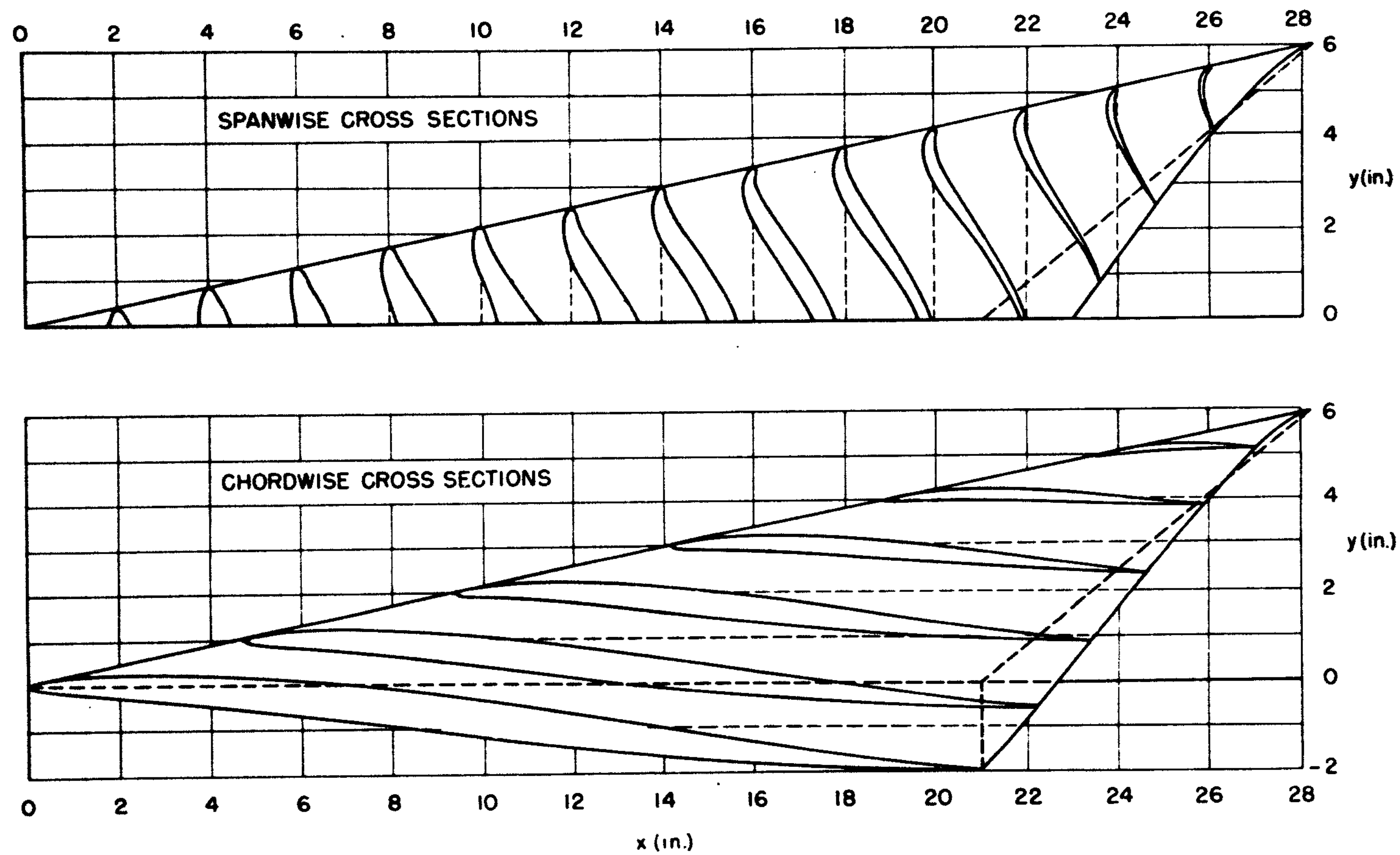


Figure 13. Spanwise and chordwise cross sections of the warped arrow wing

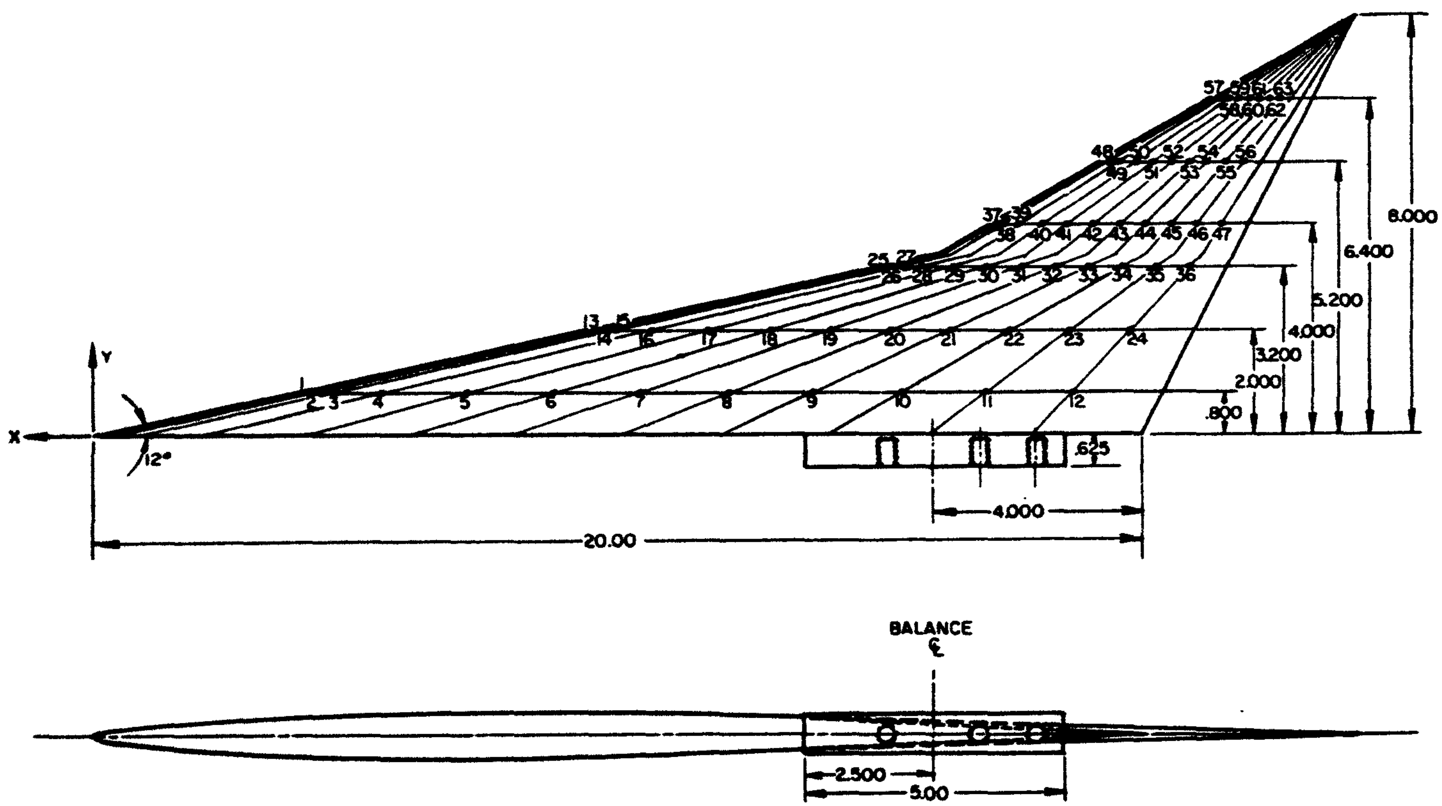
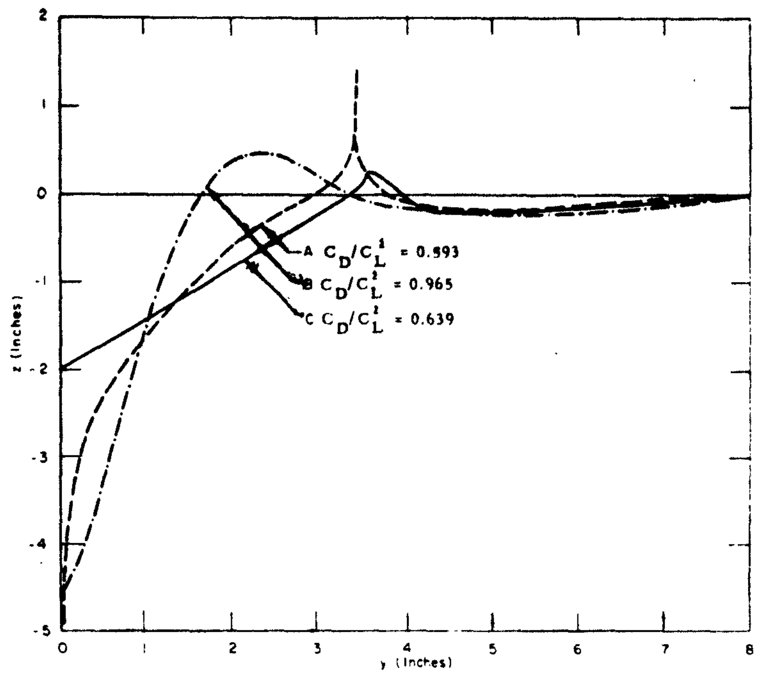


Figure 14. Drawing of double-delta wing showing the pressure tap locations



$$\bar{x} = \frac{x}{l_0} \qquad \bar{y} = \left(\frac{y}{l_0 \tan \epsilon_1}\right)$$

A $\frac{l}{q} = a_0 + a_1 \bar{x} + a_2 |\bar{y}| + a_4 \bar{y}^2$

B $\frac{l}{q} = (a_1 \bar{x} + a_2 \bar{x}^2 + a_3 \bar{x}^3)(\bar{x} - \bar{x}_0) + a_4 \left(\left(\frac{\bar{y}}{\bar{y}_0}\right)^2 - \frac{\bar{x}}{\bar{x}_0} \right) + (a_5 \bar{x} + a_6 \bar{x}^2) \left(\left(\frac{\bar{y}}{\bar{y}_0}\right)^2 - 1 \right)$

C (1) $\bar{y} < \bar{y}_0$

$$\frac{l}{q} = \frac{\bar{x}^2 - \bar{y}^2}{(\bar{x} + .01)^2 - \bar{y}^2} \left[a_0 + a_2 \bar{x}^2 + a_4 \bar{y}^2 \right] \equiv \frac{l}{q}^{(i)}$$

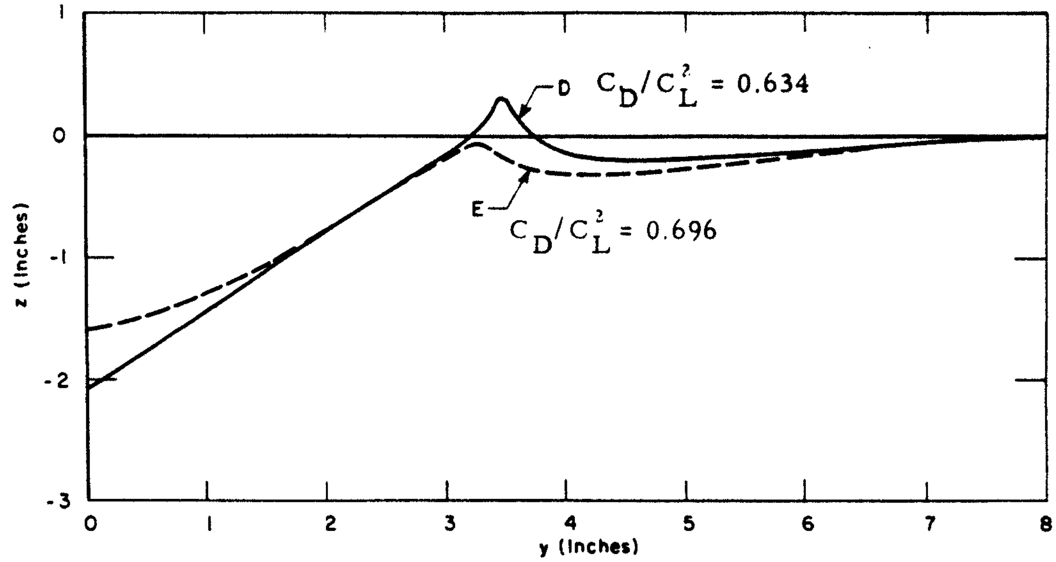
(2) $\bar{y}_0 < \bar{y} < \bar{x}$

$$\frac{l}{q} = \frac{l}{q}^{(i)} \left[1 - \frac{(\bar{y} - \bar{y}_0)^2}{(\bar{y} - \bar{y}_0)^2 + .01} \right] + \frac{l}{q}^{(o)}$$

(3) $\bar{y} > \bar{x}$

$$\frac{l}{q} = \frac{(\bar{y} - \bar{y}_0)^2}{(\bar{y} - \bar{y}_0)^2 + .01} \left[a_{10} + a_{11} (x - \bar{x}) + a_{12} (x - \bar{x})^2 \right] \equiv \frac{l}{q}^{(o)}$$

Figure 15a. Trailing-edge ordinates for various loadings on double-delta wind tunnel model planform



D (1.) $\bar{y} < \bar{y}_0$

$$\frac{\ell}{q} = \frac{\bar{x}^2 - \bar{y}^2}{(\bar{x} + .01)^2 - \bar{y}^2}\left[a_1\bar{x} + a_2\bar{x}^2 + a_4\bar{y}^2\right]$$

(2.) $\bar{y} > \bar{y}_c$

$$\frac{\ell}{q} = \left(\frac{\bar{x} + \bar{y}}{(\bar{x} + .01) + \bar{y}}\right)\frac{(x - x_c)}{(x - x_c + \bar{c})}\left[a_1\bar{x} + a_2\bar{x}^2 + a_4\bar{y}^2\right] + (\bar{y} - \bar{y}_c)^2\left[a_3 + a_5(\bar{x} - \bar{x}_c)\right]$$

$$\bar{c} = .01\left[1 + \frac{\bar{y} - \bar{y}_c}{\bar{x} - \bar{x}_c}\right]$$

E (1.) $\bar{y} < \bar{y}_c$

$$\frac{\ell}{q} = \frac{\bar{x}^2 - \bar{y}^2}{(\bar{x} + .01)^2 - \bar{y}^2}\left[(a_1\bar{x} + a_2\bar{x}^2 + a_4\bar{y}^2)F(\eta) + a_3\bar{x}(\bar{x} - \bar{x}_c)\right] + (a_5 + a_6\bar{x})(\bar{y}^2 - \bar{x}^2)$$

(2.) $\bar{y} > \bar{y}_c$

$$\frac{\ell}{q} = \left(\frac{\bar{x} + \bar{y}}{(\bar{x} + .01) + \bar{y}}\right)\frac{\bar{x} - \bar{x}_c}{\bar{x} - \bar{x}_c + \bar{c}}\left[(a_1\bar{x} + a_2\bar{x}^2 + a_4\bar{y}^2)F(\eta) + a_3\bar{x}(\bar{x} - \bar{x}_c)\right] + (a_5 + a_6\bar{x})(\bar{y}^2 - \bar{x}^2)$$

$$\bar{c} = .01\left[1 + \frac{\bar{y} - \bar{y}_c}{\bar{x} - \bar{x}_c} + \frac{(\bar{y} - \bar{y}_c)^2}{(\bar{x} - \bar{x}_c)^2}\right]$$

$$\eta = \sqrt{M^2 - 1}\,(\tan\epsilon_1)\,\frac{\bar{y} - \bar{y}_c}{\bar{x} - \bar{x}_c}$$

$$F(\eta) = 1 \qquad \eta < -1$$

$$= 1 + \left(\frac{\tan\epsilon_2}{\tan\epsilon_1} - 1\right)\left(\frac{1 + \eta}{1 + \beta\tan\epsilon_2}\right)^2, \ \eta > -1 \ \ \bar{x} > \bar{x}_c \text{ and } \beta = \sqrt{M^2 - 1}$$

Figure 15b. Trailing-edge ordinates for various loadings on double-delta wind tunnel model planform

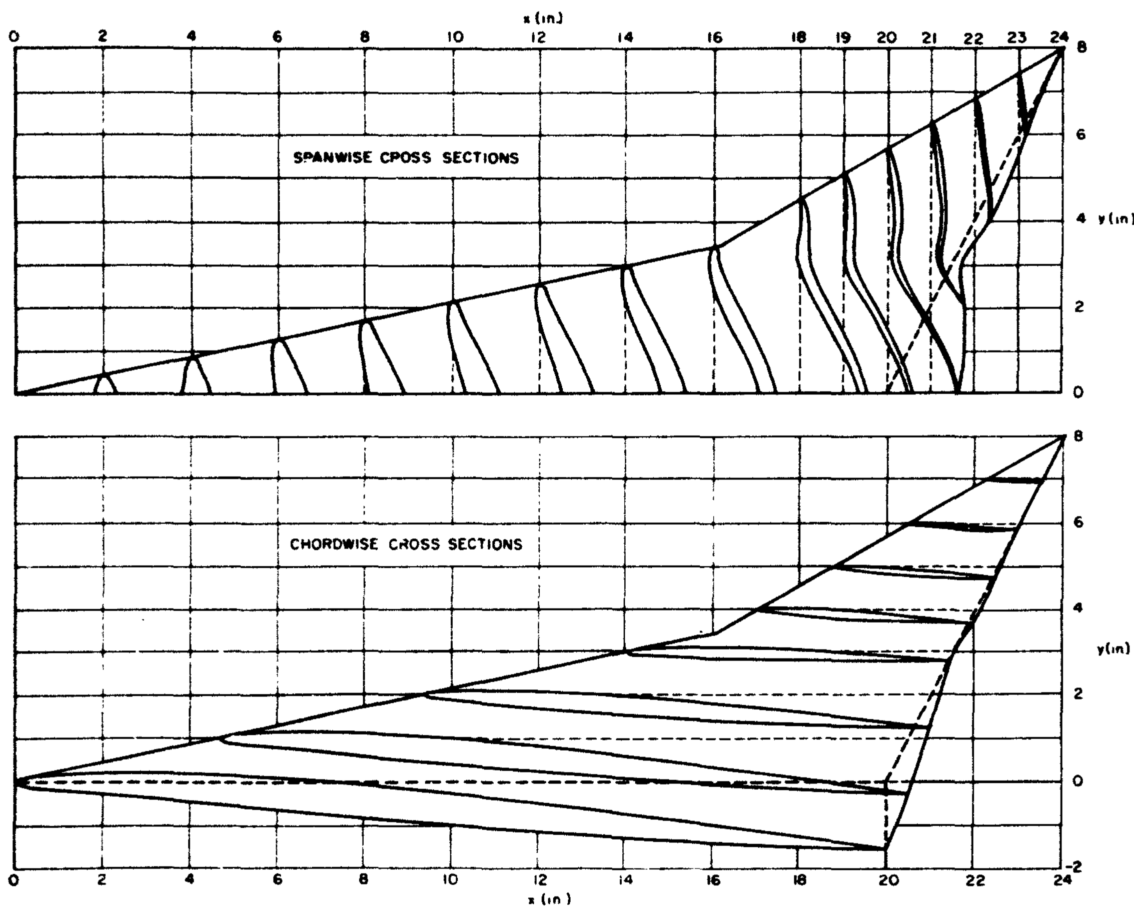


Figure 16. Spanwise and chordwise cross sections of the warped double-delta wing

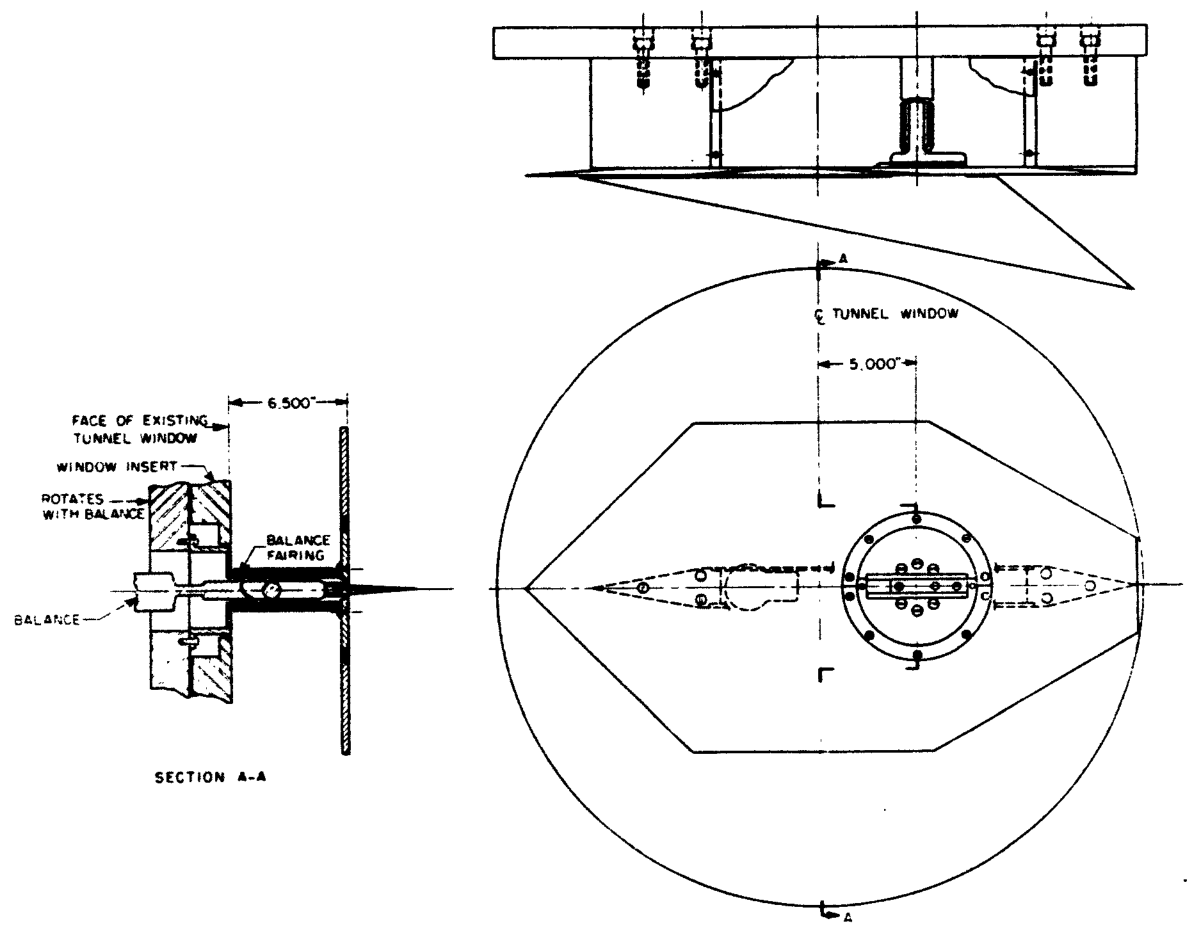


Figure 17. Flat arrow wing mounted on boundary layer plate

Figure 18. Photograph of lamp black and oil pattern on the top of the flat arrow wing at 4° angle of attack

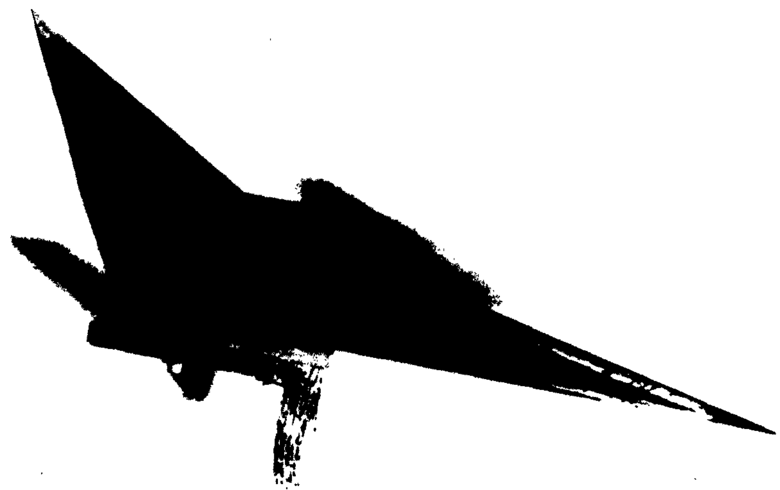


Figure 19. Photograph of the lamp black and oil pattern on the top of the warped double-delta wing at 0° angle of attack

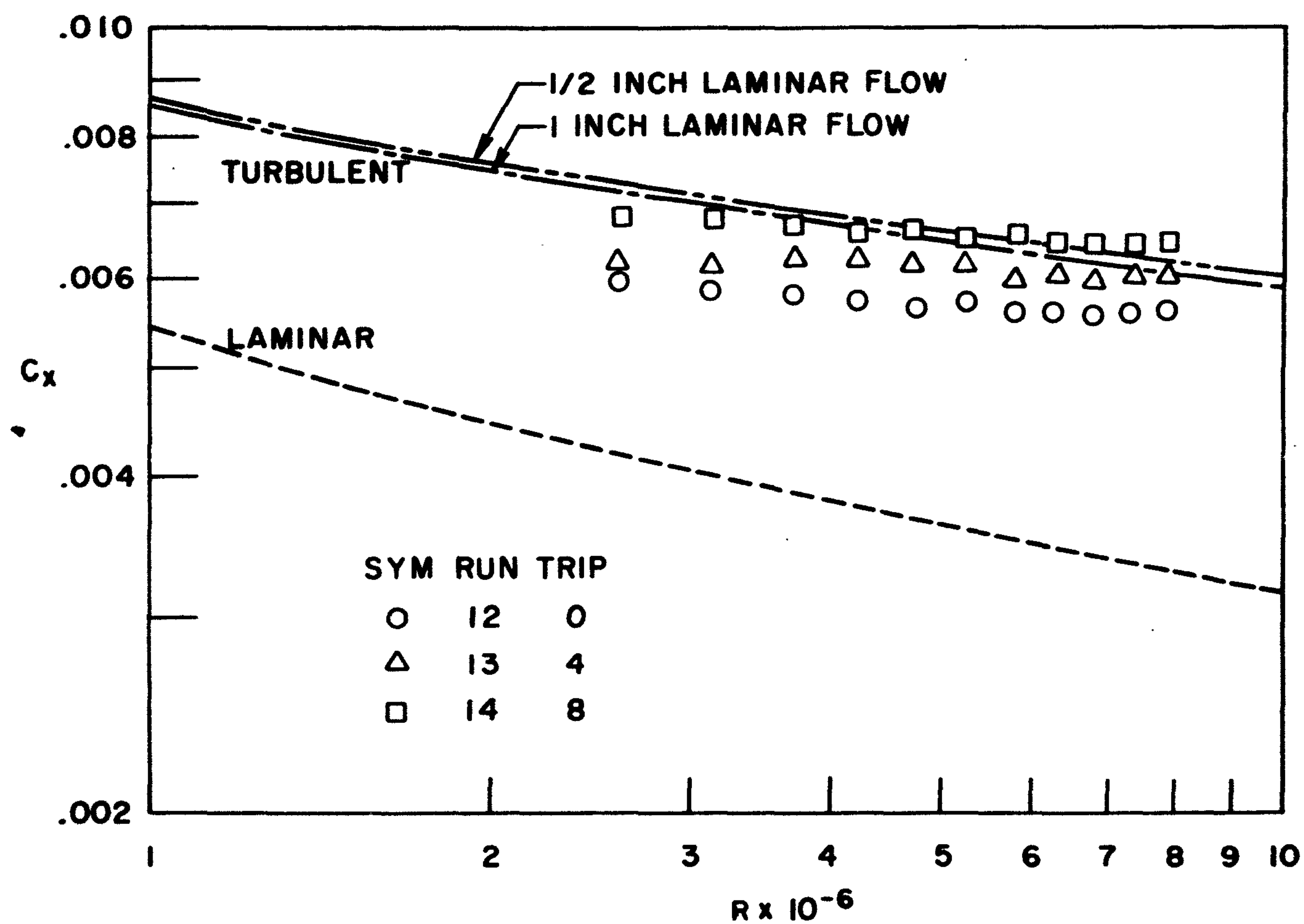


Figure 20. Flat arrow wing - drag vs. Reynolds number

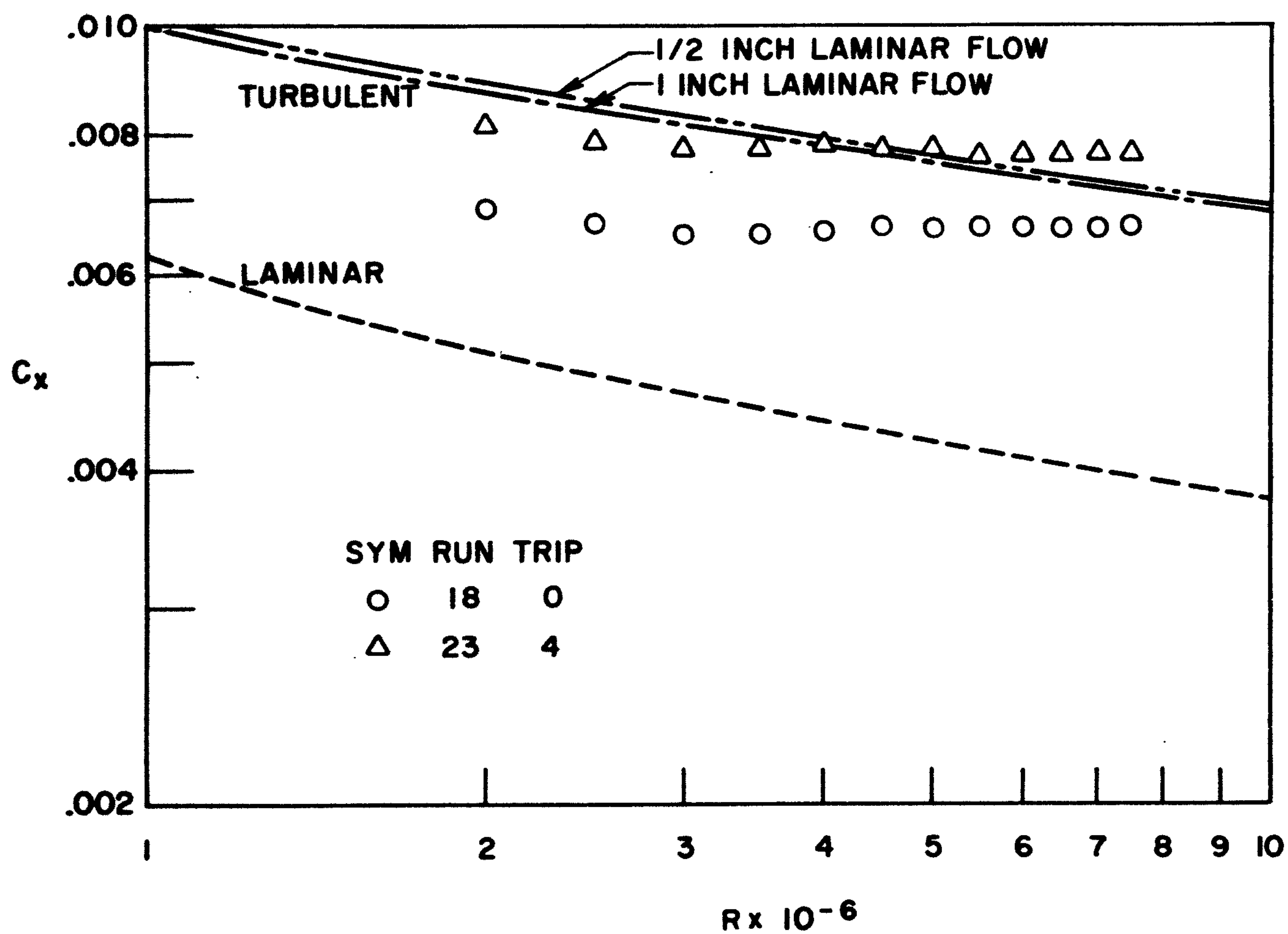


Figure 21. Flat double-delta wing - drag vs. Reynolds number

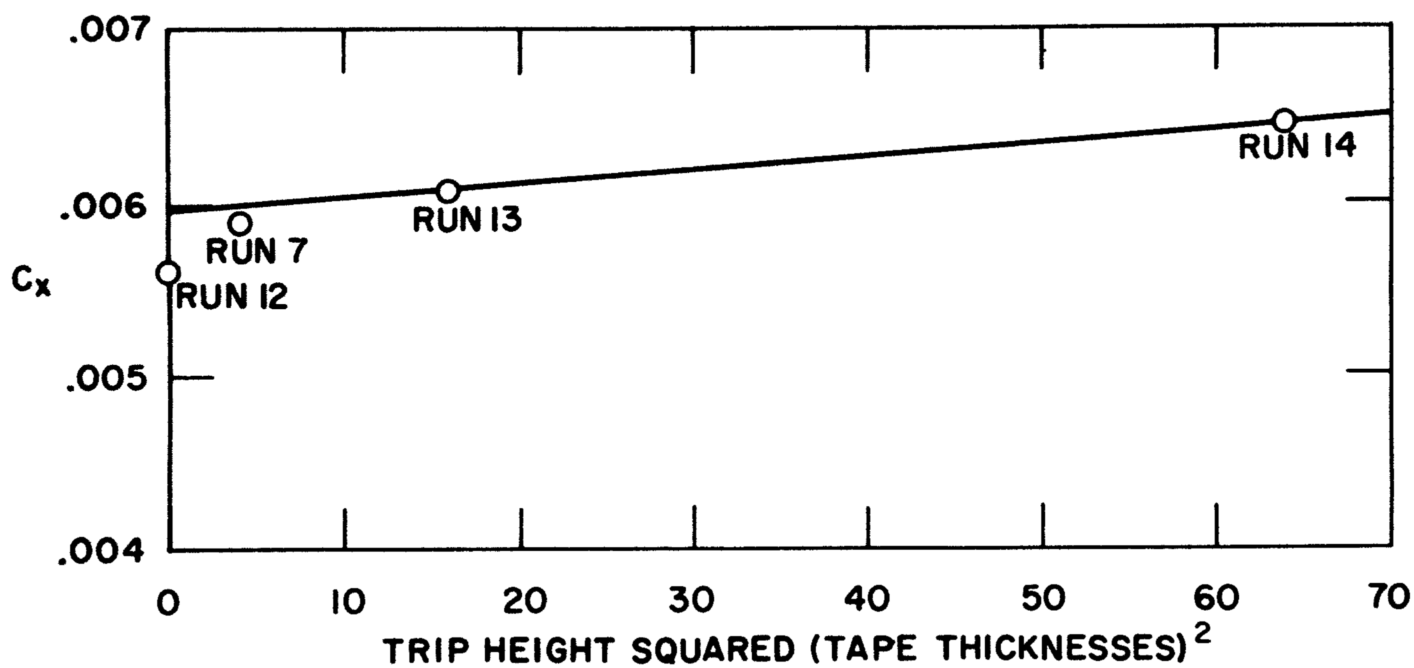


Figure 22. Axial force coefficient vs. trip height squared; flat arrow wing

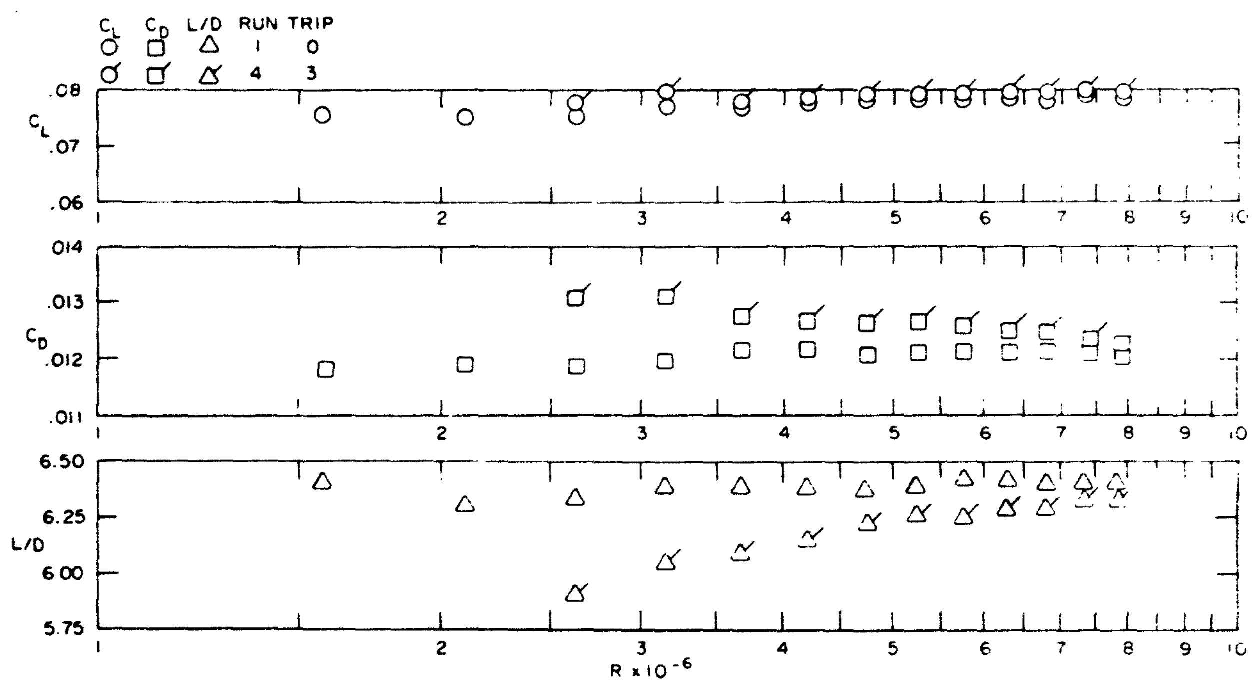


Figure 23. Lift, drag and lift drag ratio vs. Reynolds number for the warped arrow wing

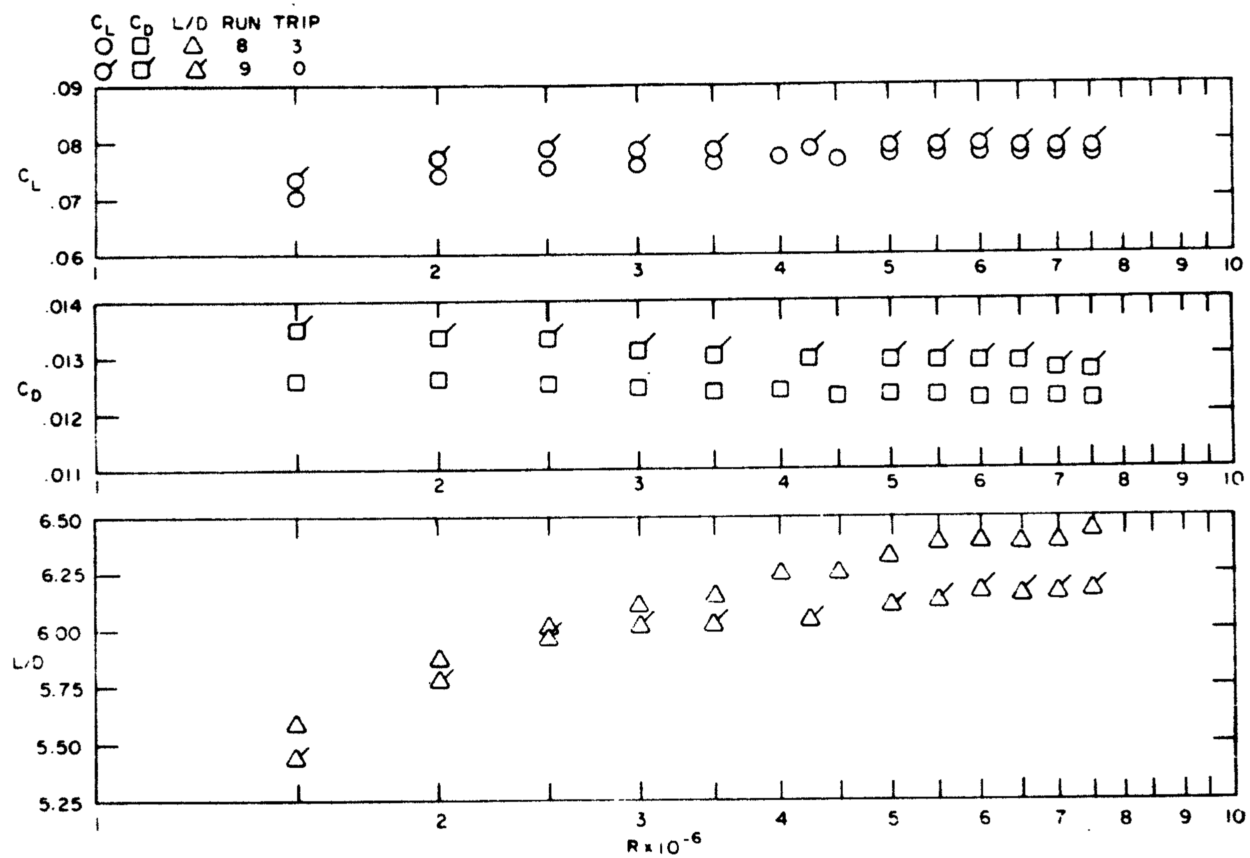


Figure 24. Lift, drag and lift drag ratio vs. Reynolds number for the warped double-delta wing

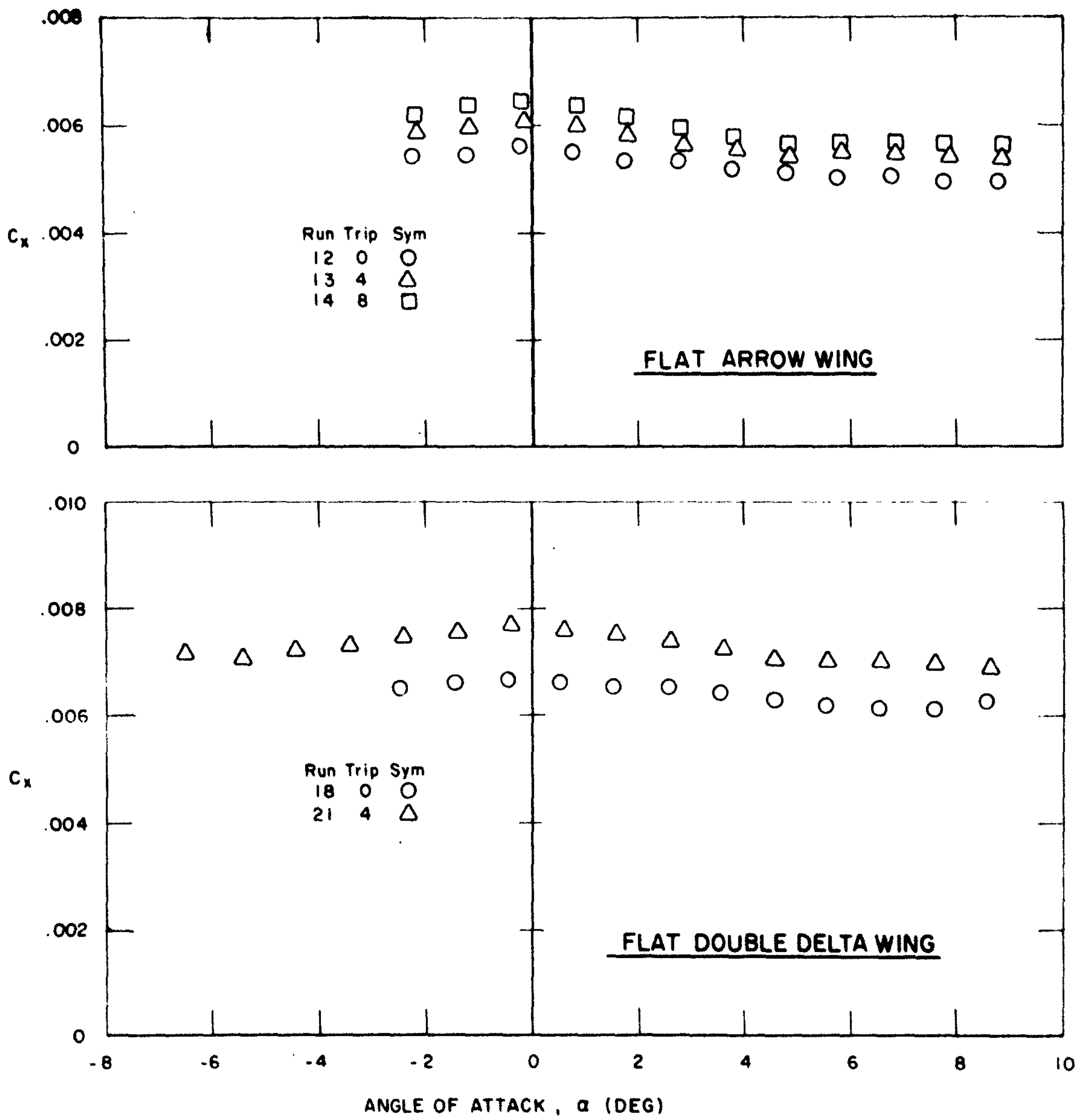


Figure 25. Axial force vs. angle of attack for the flat wings

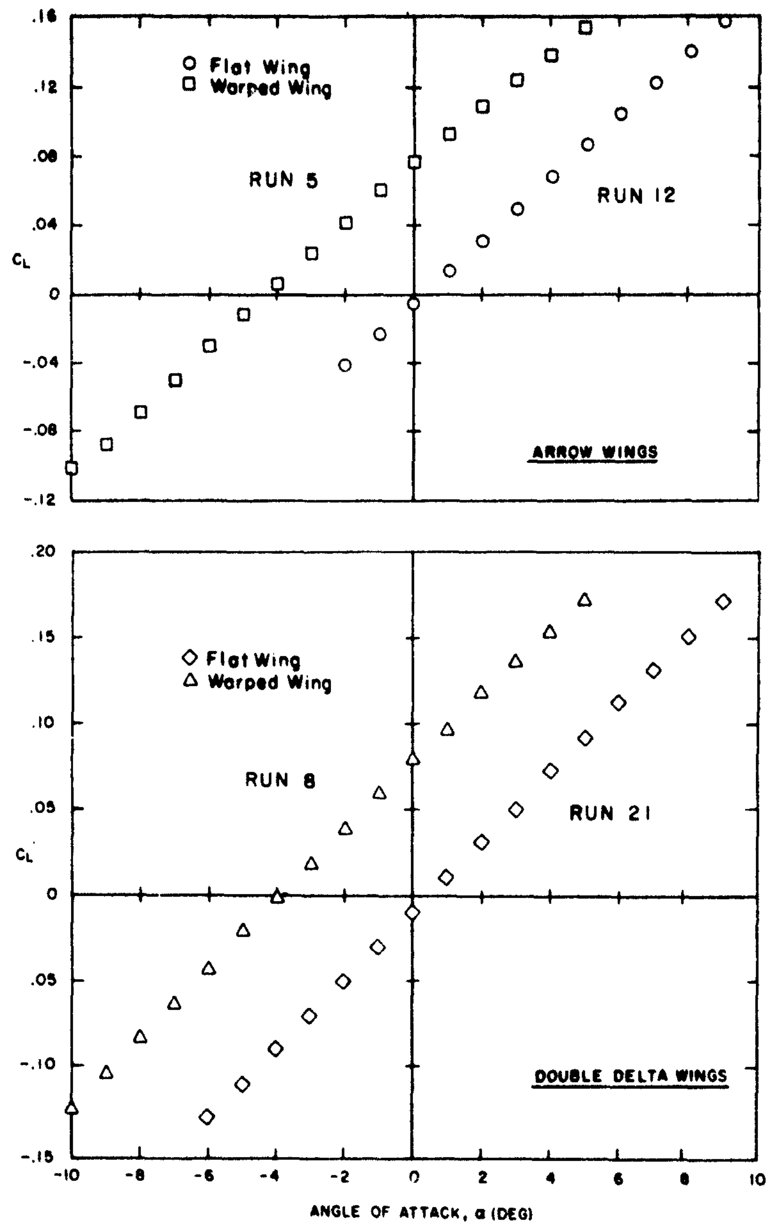


Figure 26. Lift vs. angle of attack for all wings

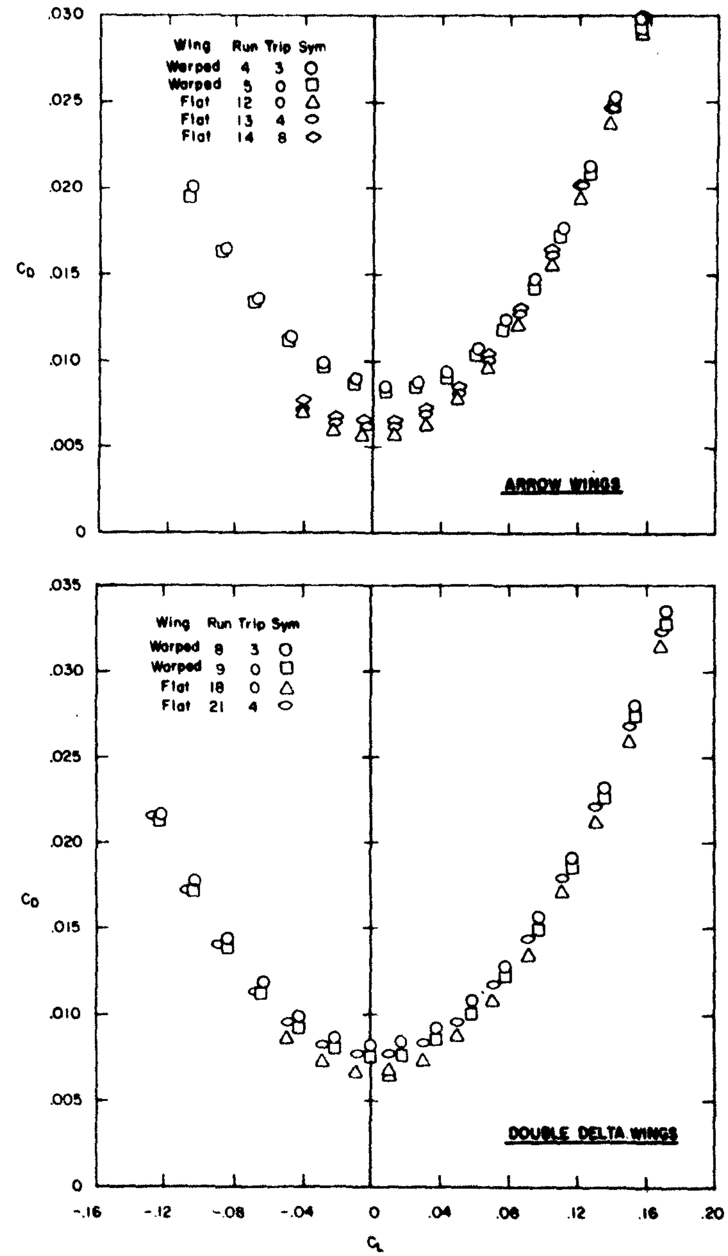


Figure 27. Lift vs. drag for all wings

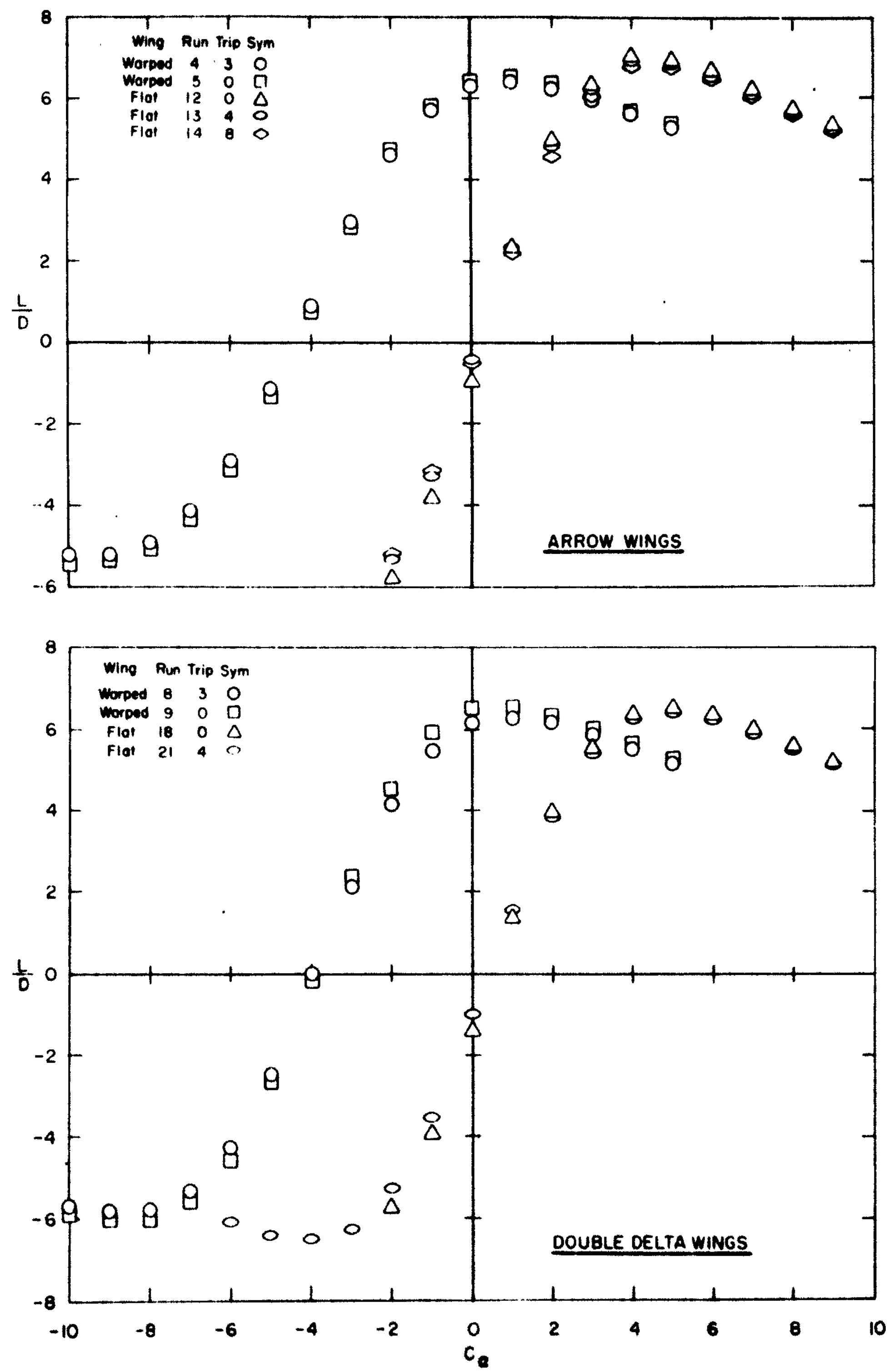


Figure 28. Lift-drag ratio vs. angle of attack for all wings

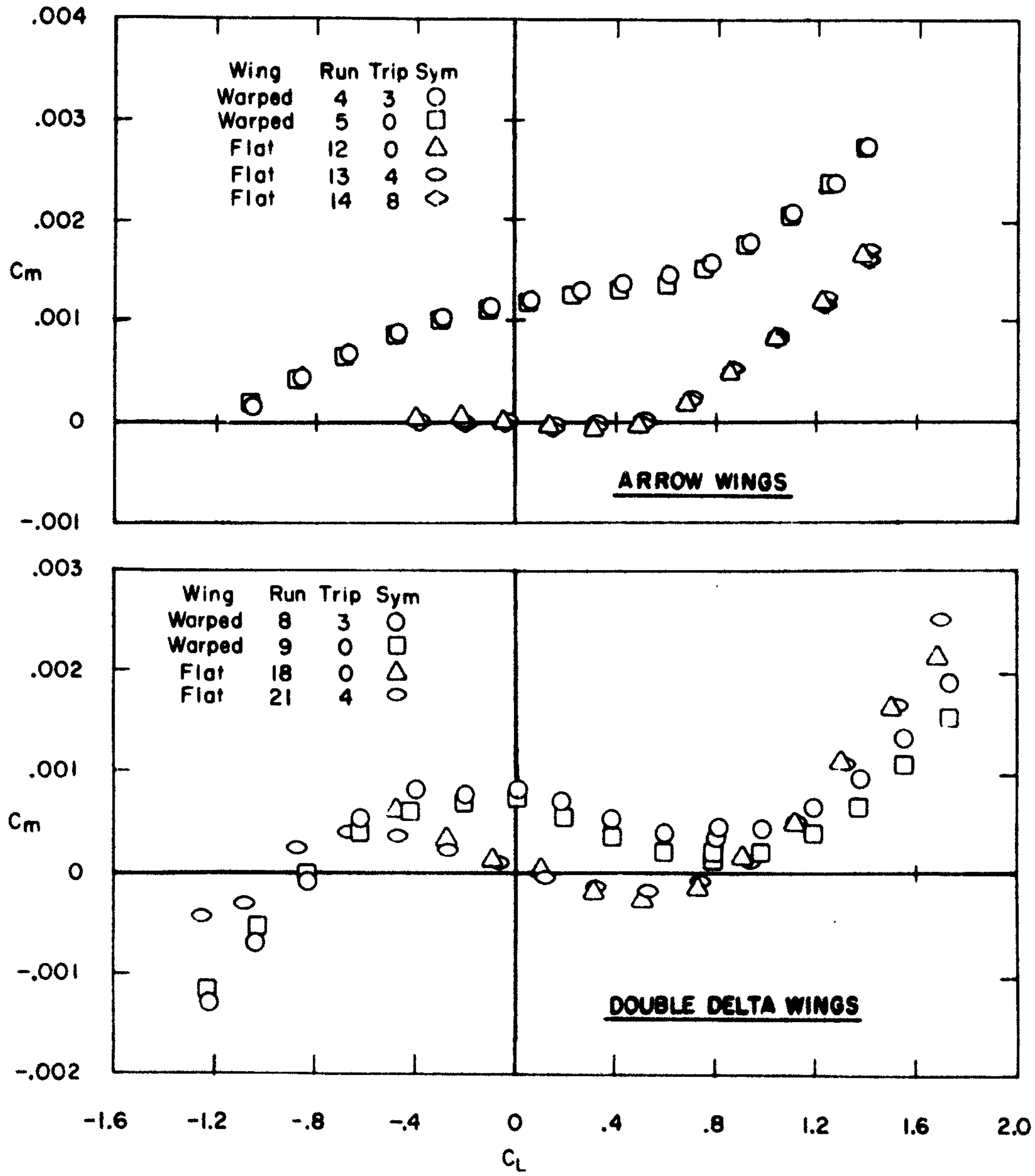


Figure 29. Pitching moment vs. lift for all wings

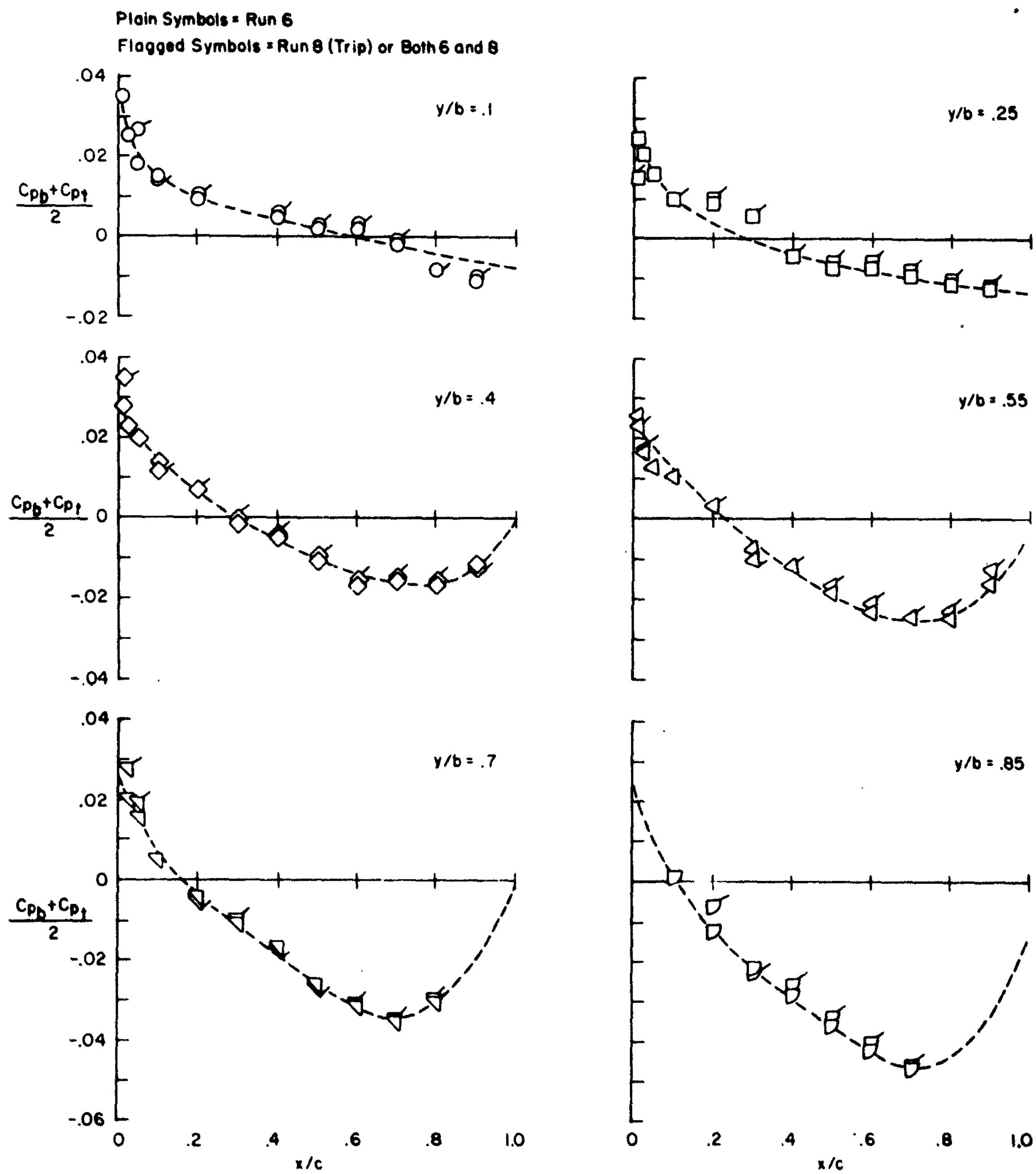


Figure 30. Thickness pressure distribution for the flat arrow wing

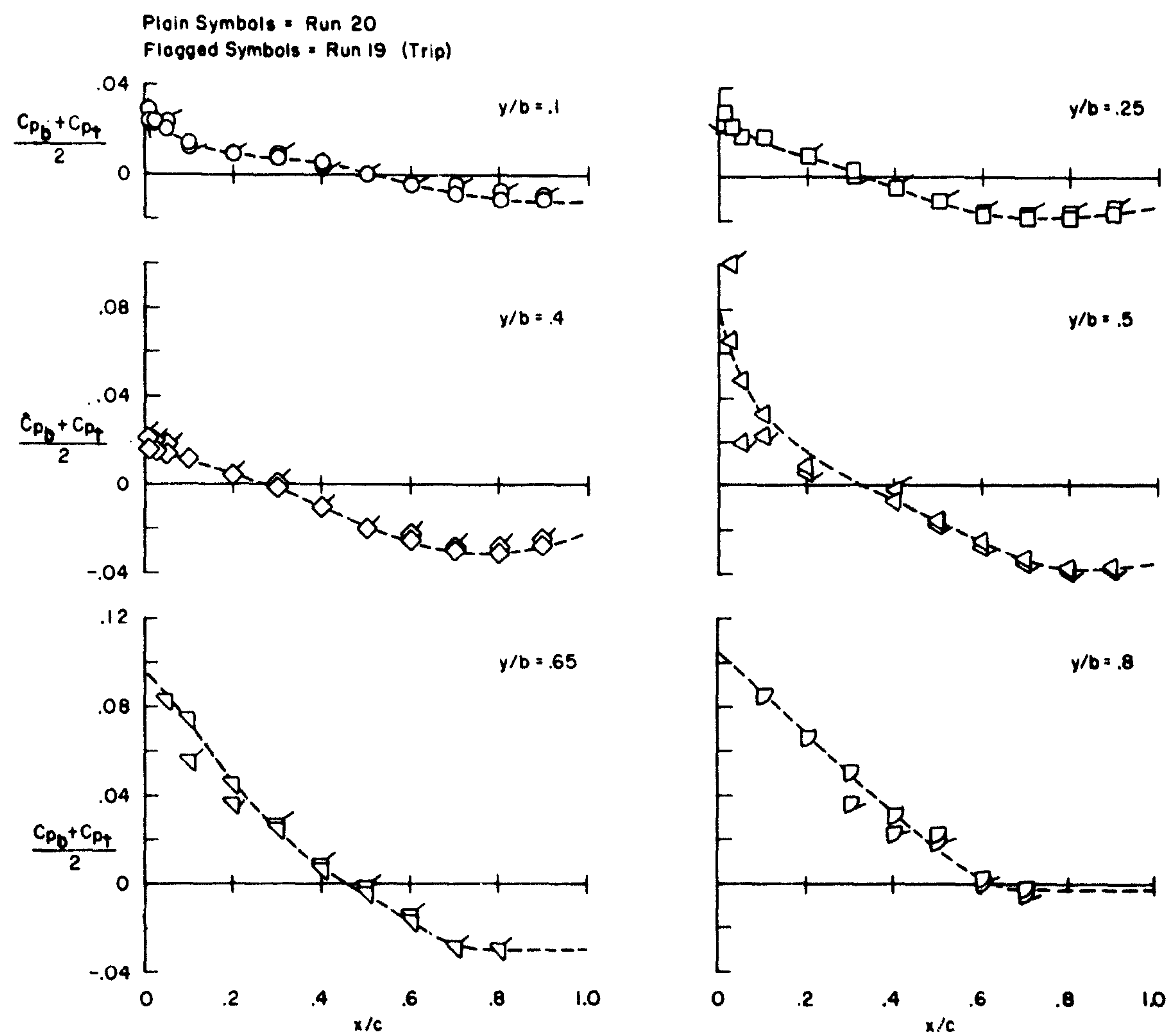


Figure 31. Thickness pressure distribution for the flat double-delta

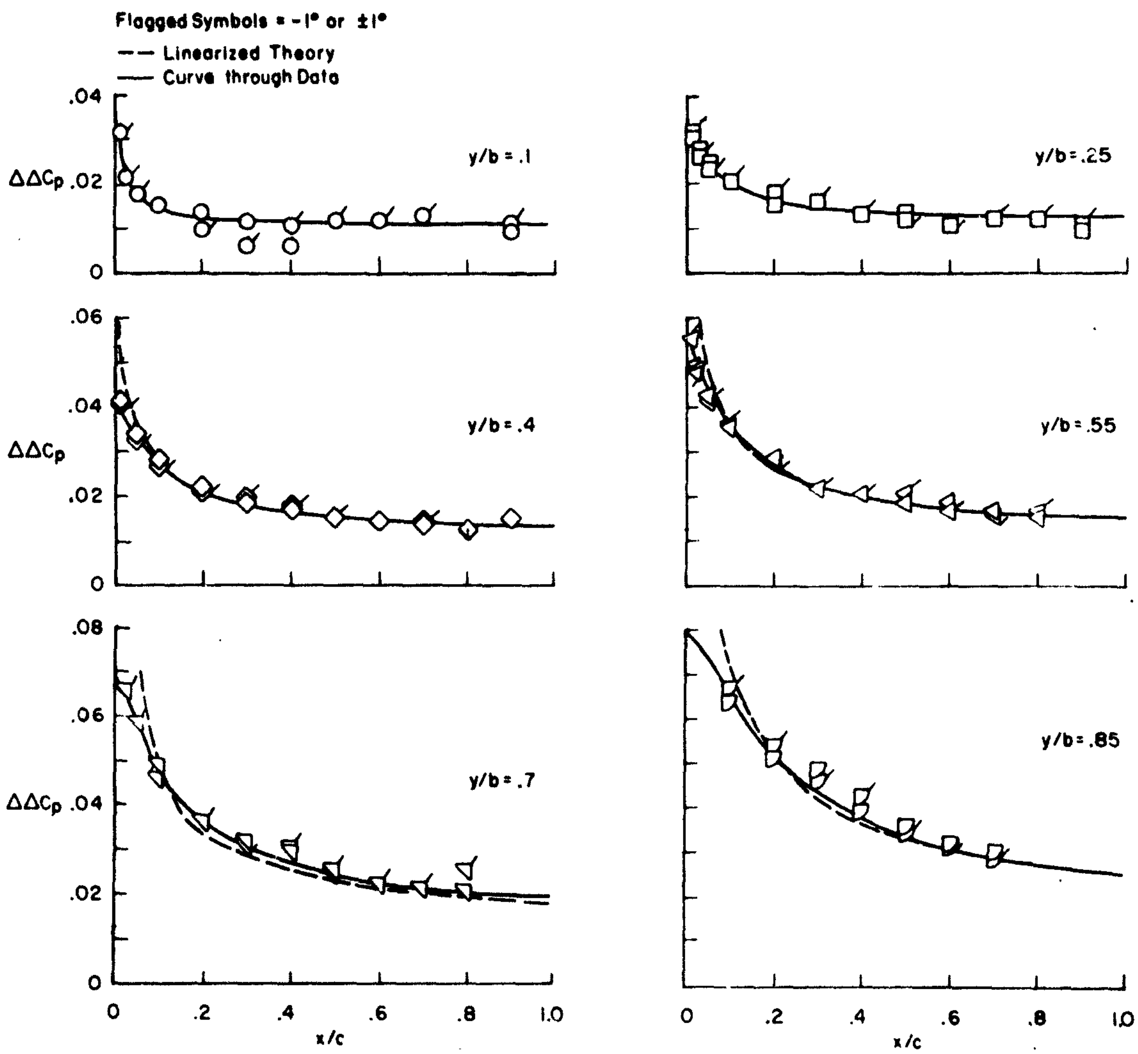


Figure 32. Pressure difference for 1° angle of attack for flat arrow wing and comparison with linearized theory

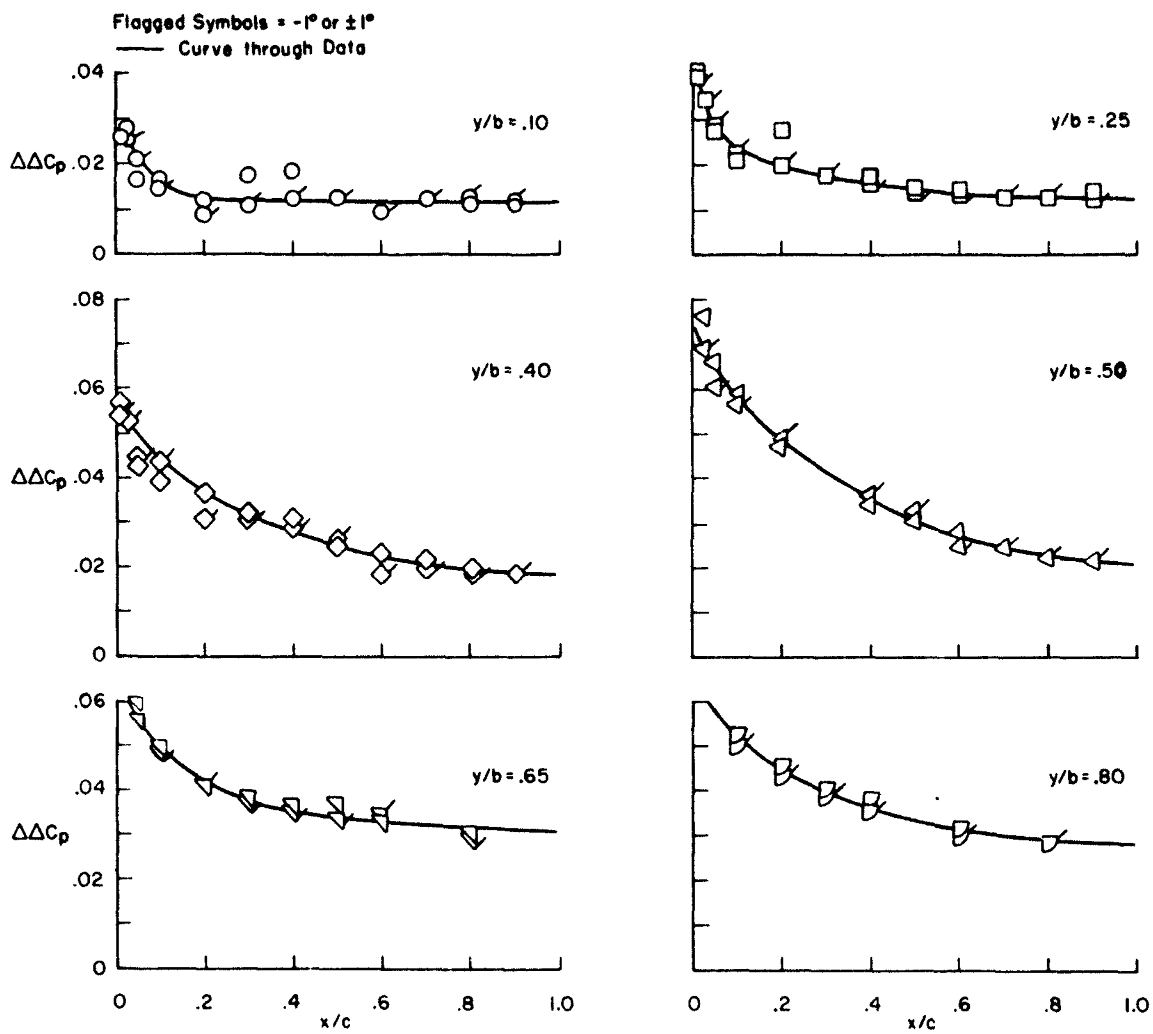


Figure 33. Pressure difference for 1° angle of attack for the flat double delta wing

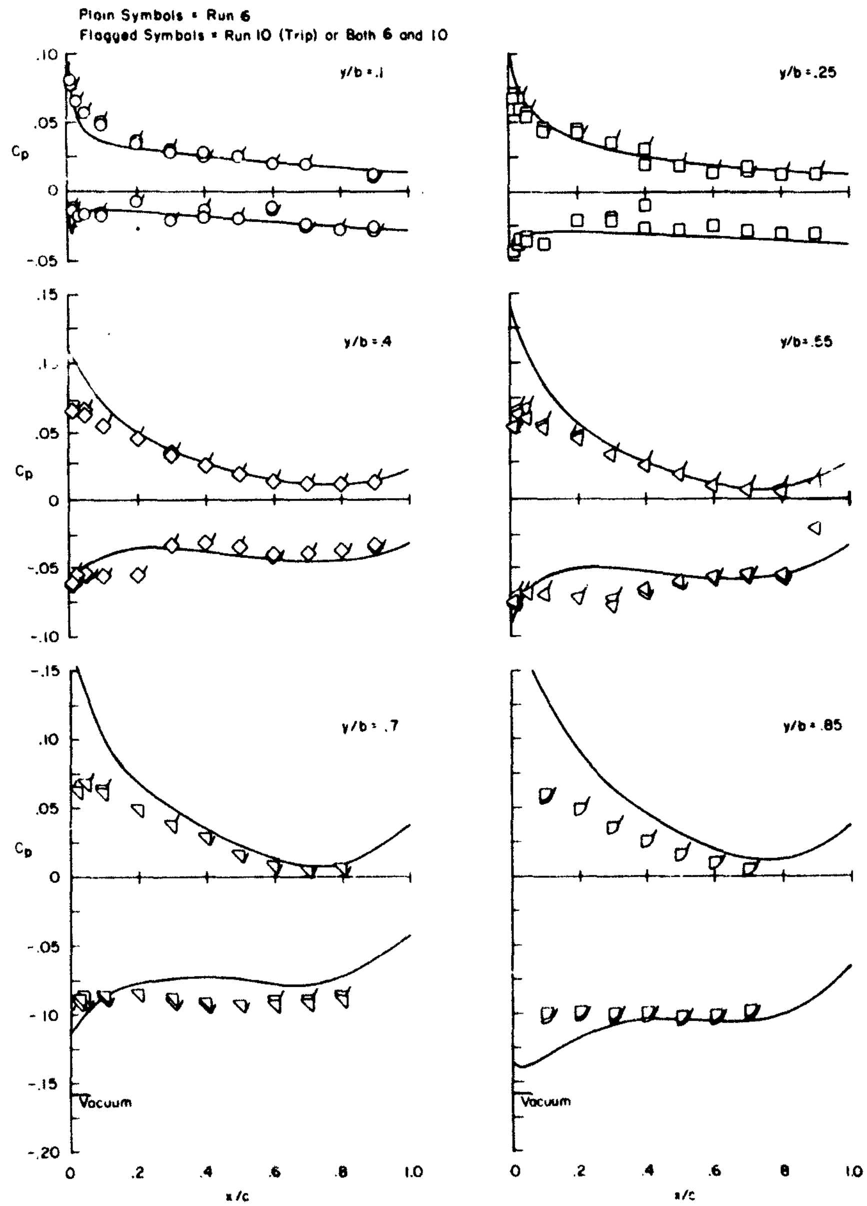


Figure 34. Predicted and measured pressure distribution on flat arrow wing at 4° angle of attack

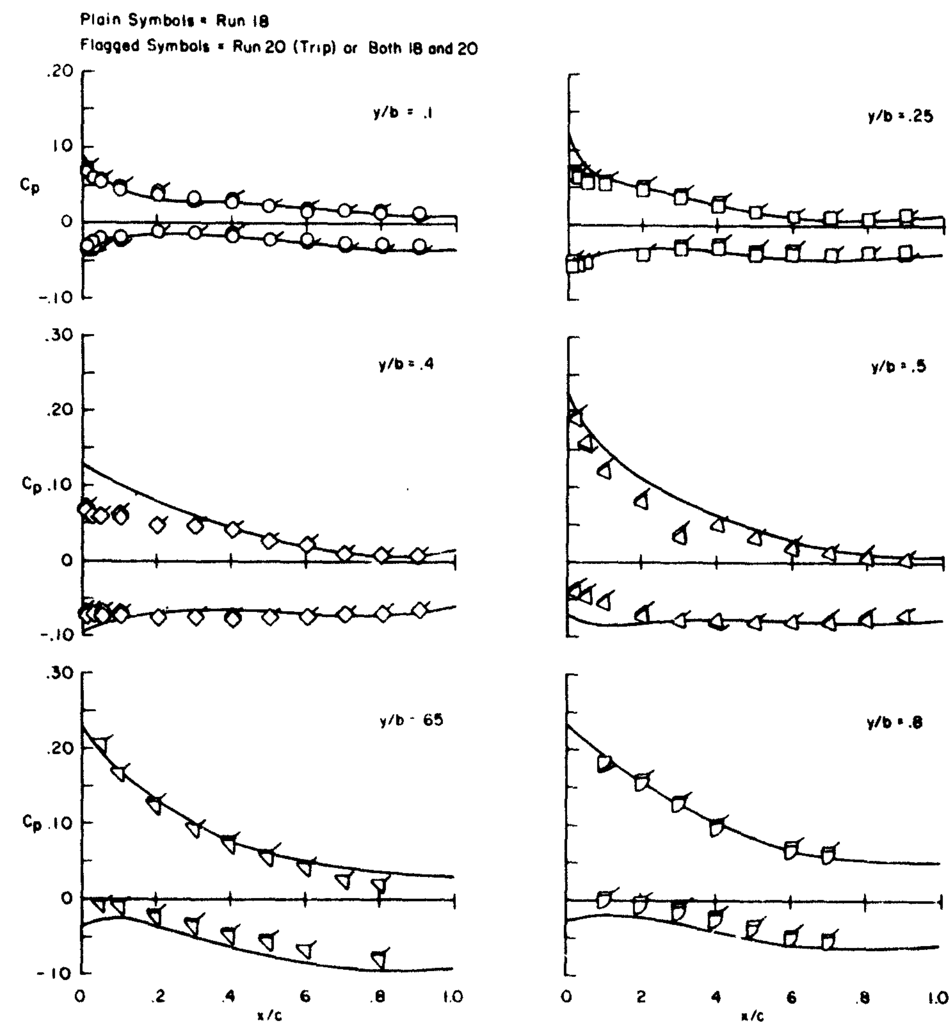


Figure 35. Predicted and measured pressure distribution on the flat double-delta wing at 4° angle of attack

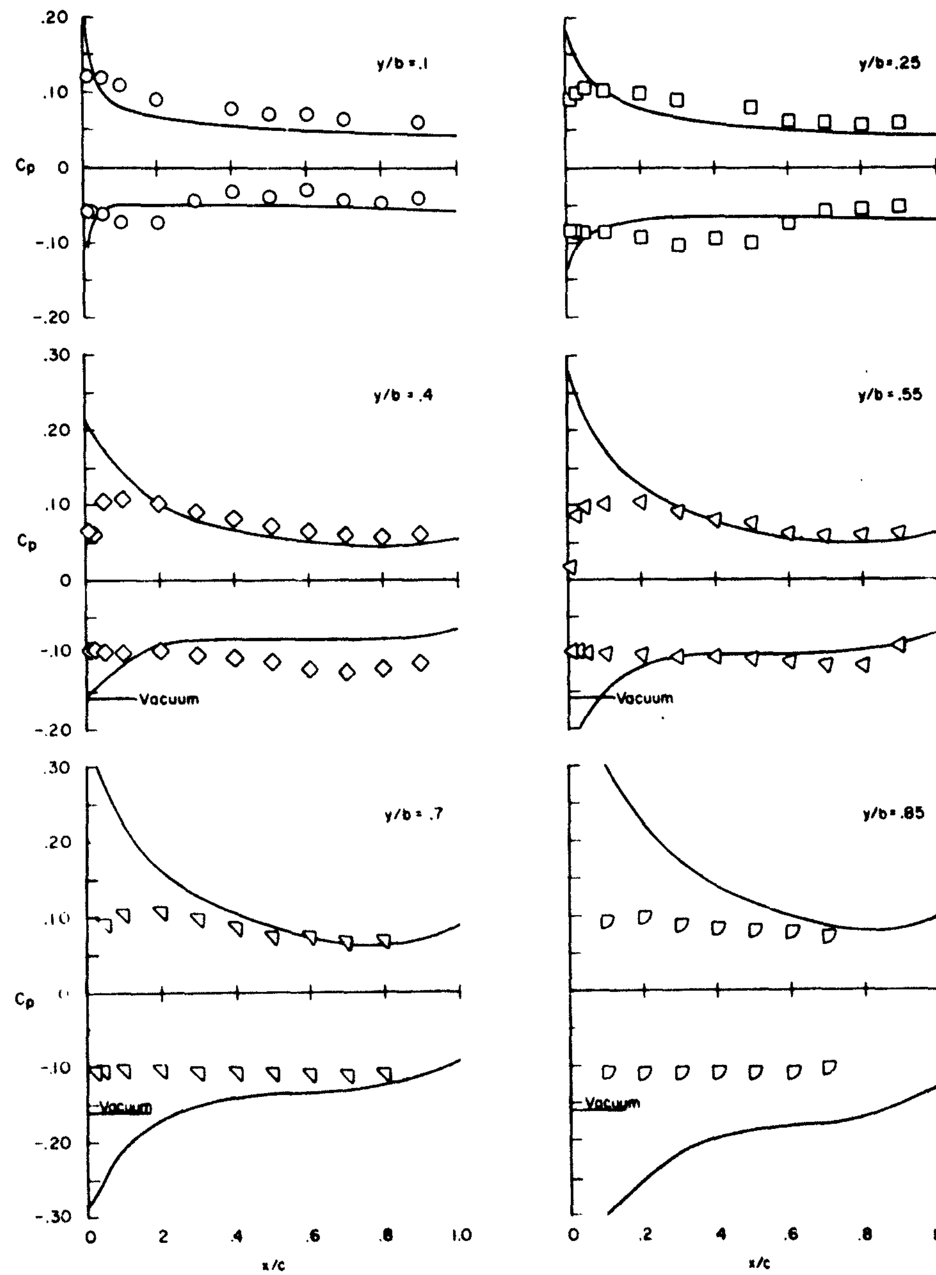


Figure 36. Predicted and measured pressure distribution on the flat arrow wing at 9° angle of attack

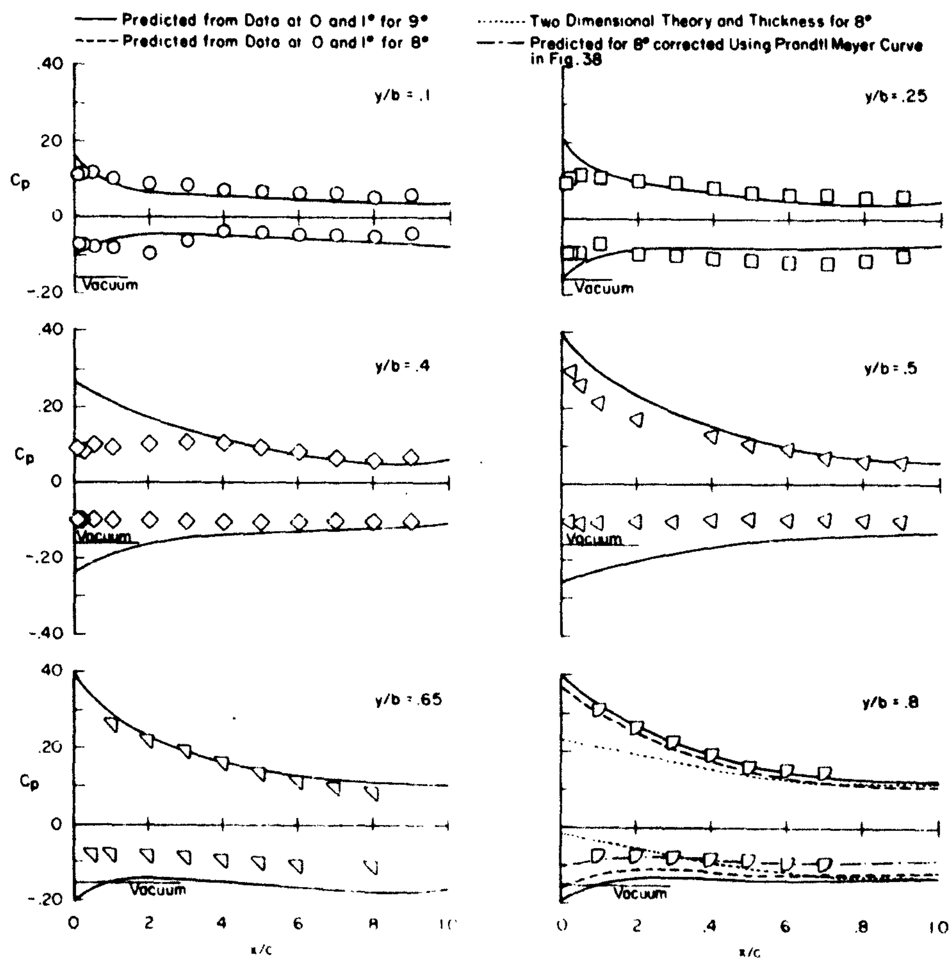


Figure 37. **Predicted and measured pressure distribution on the flat double delta wing at 9° angle of attack**

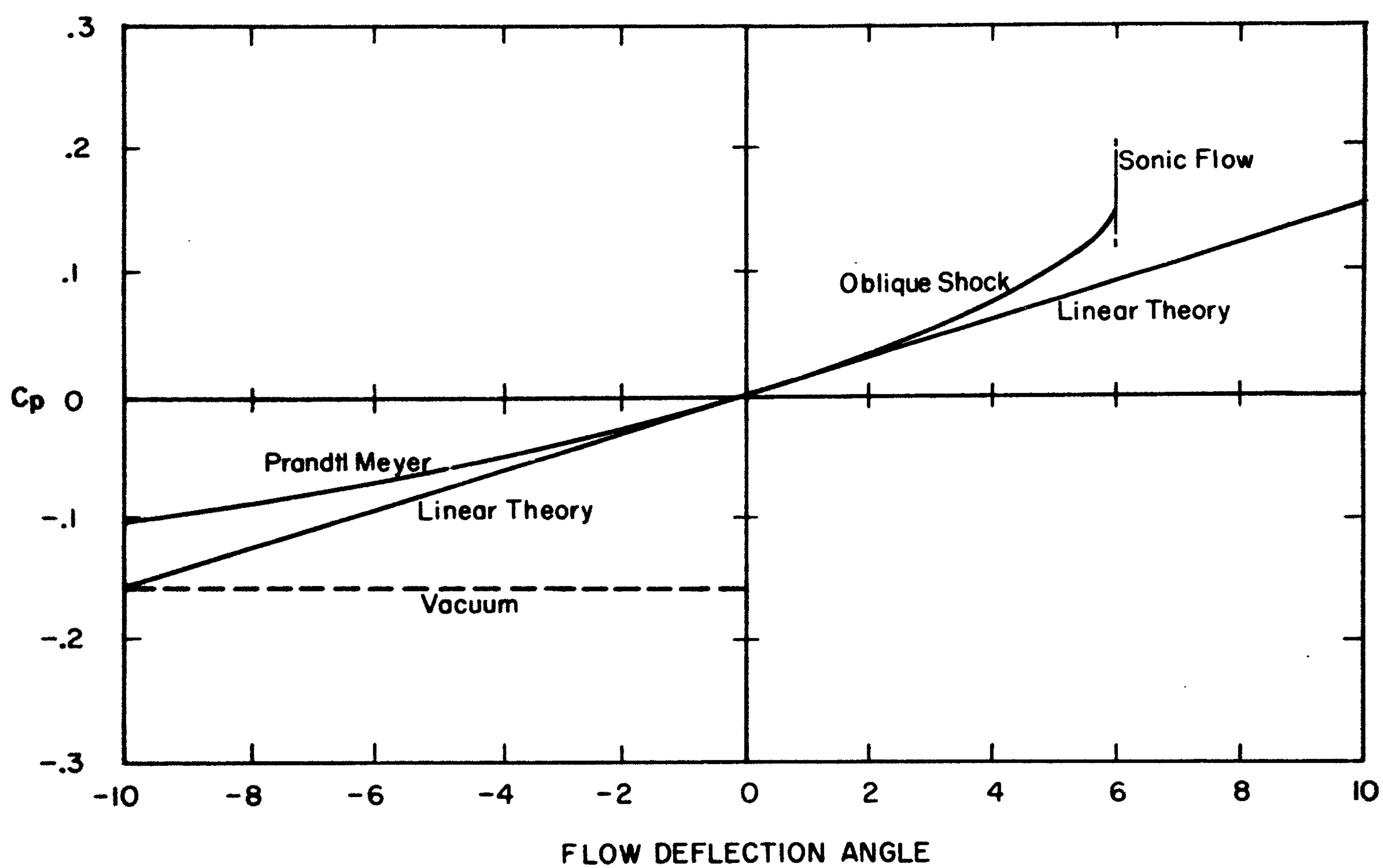


Figure 38. Comparison of linear theory and shock expansion theory for a two-dimensional 60° swept wing at Mach number 3

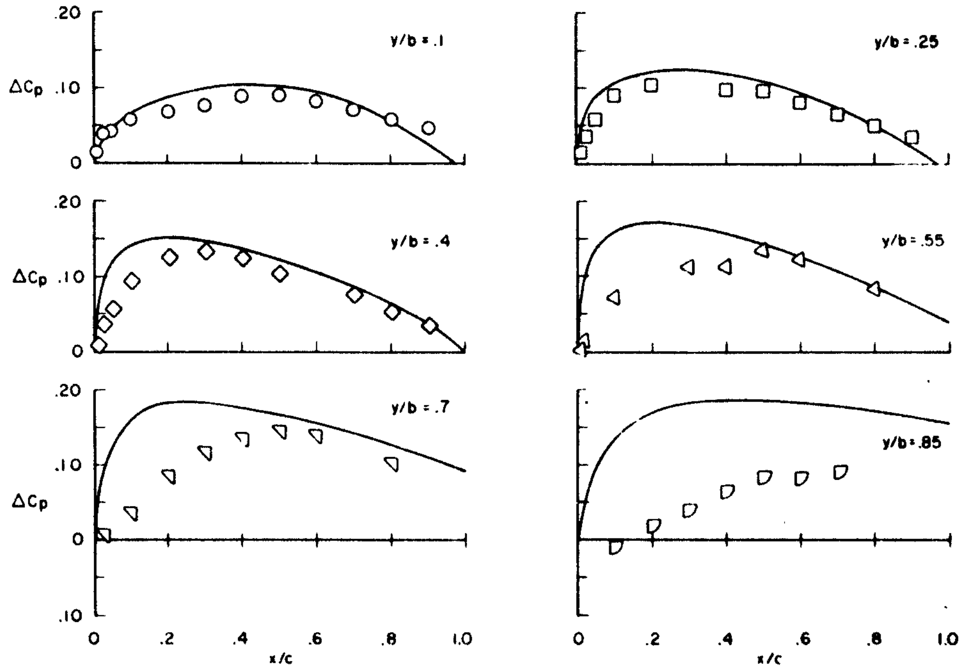


Figure 39. Comparison of experimental and predicted pressure difference for the warped arrow wing

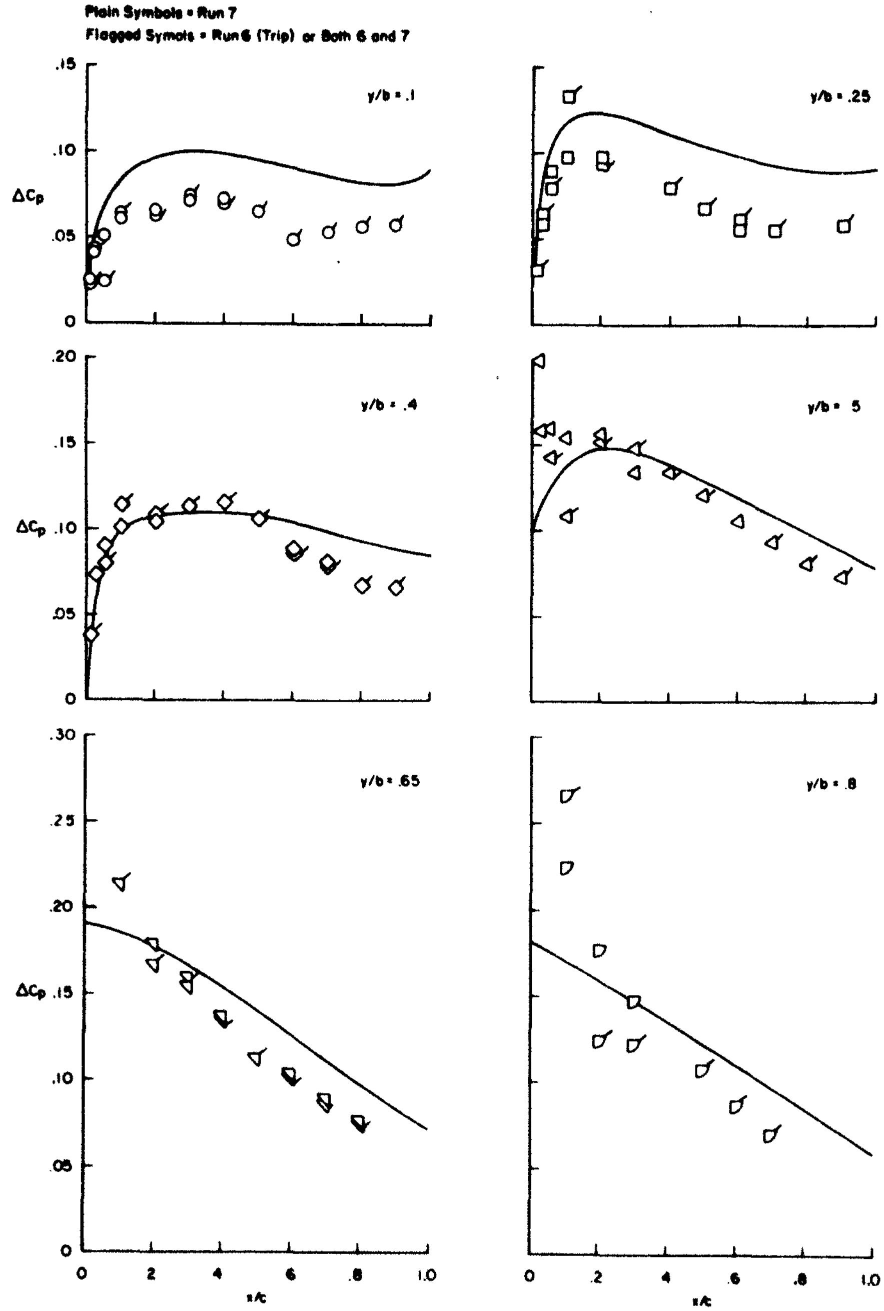


Figure 40. Comparison of the predicted and measured pressure difference on the warped double-delta wing

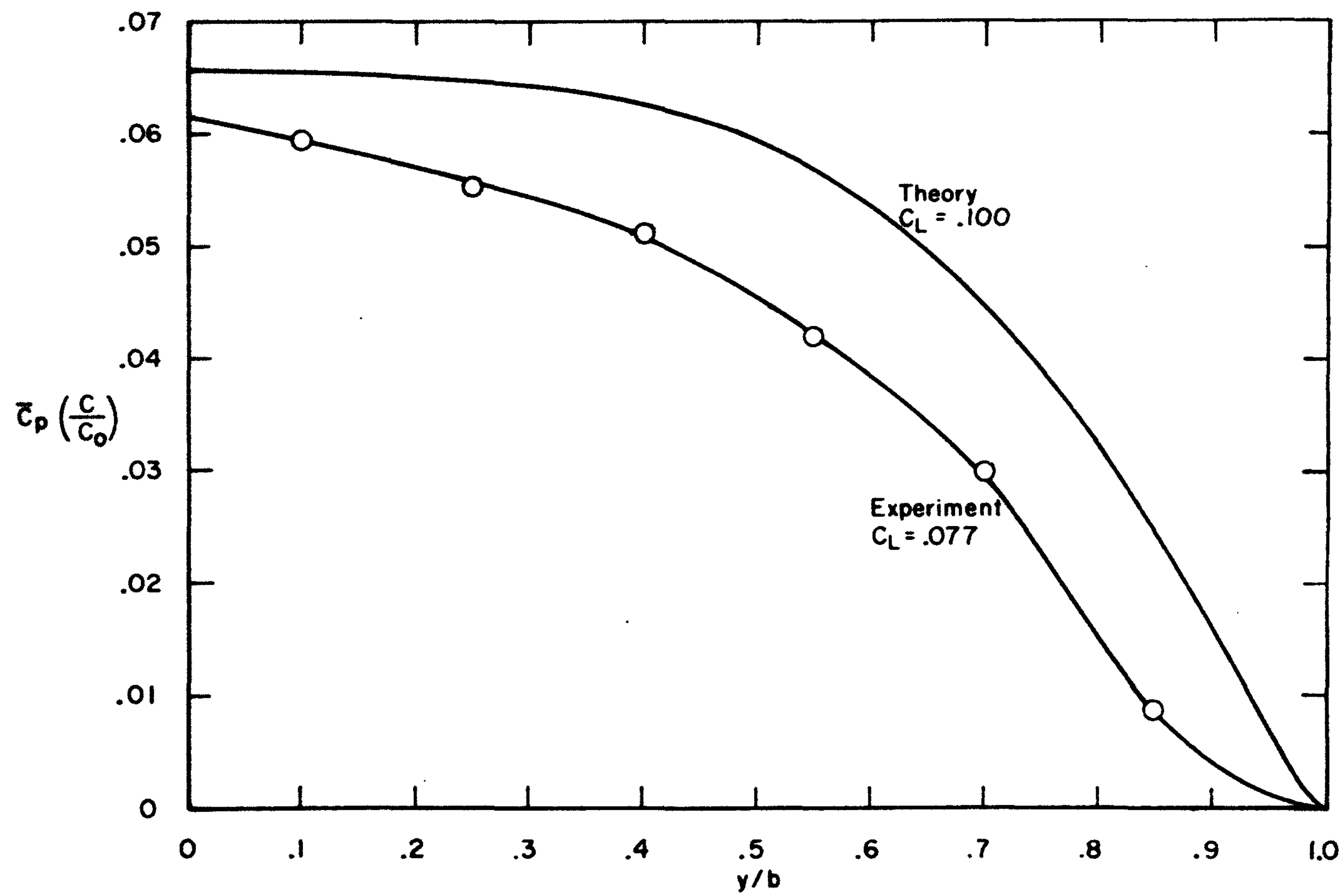


Figure 41a. Comparison of theoretical and experimental spanwise loading for the warped arrow wing

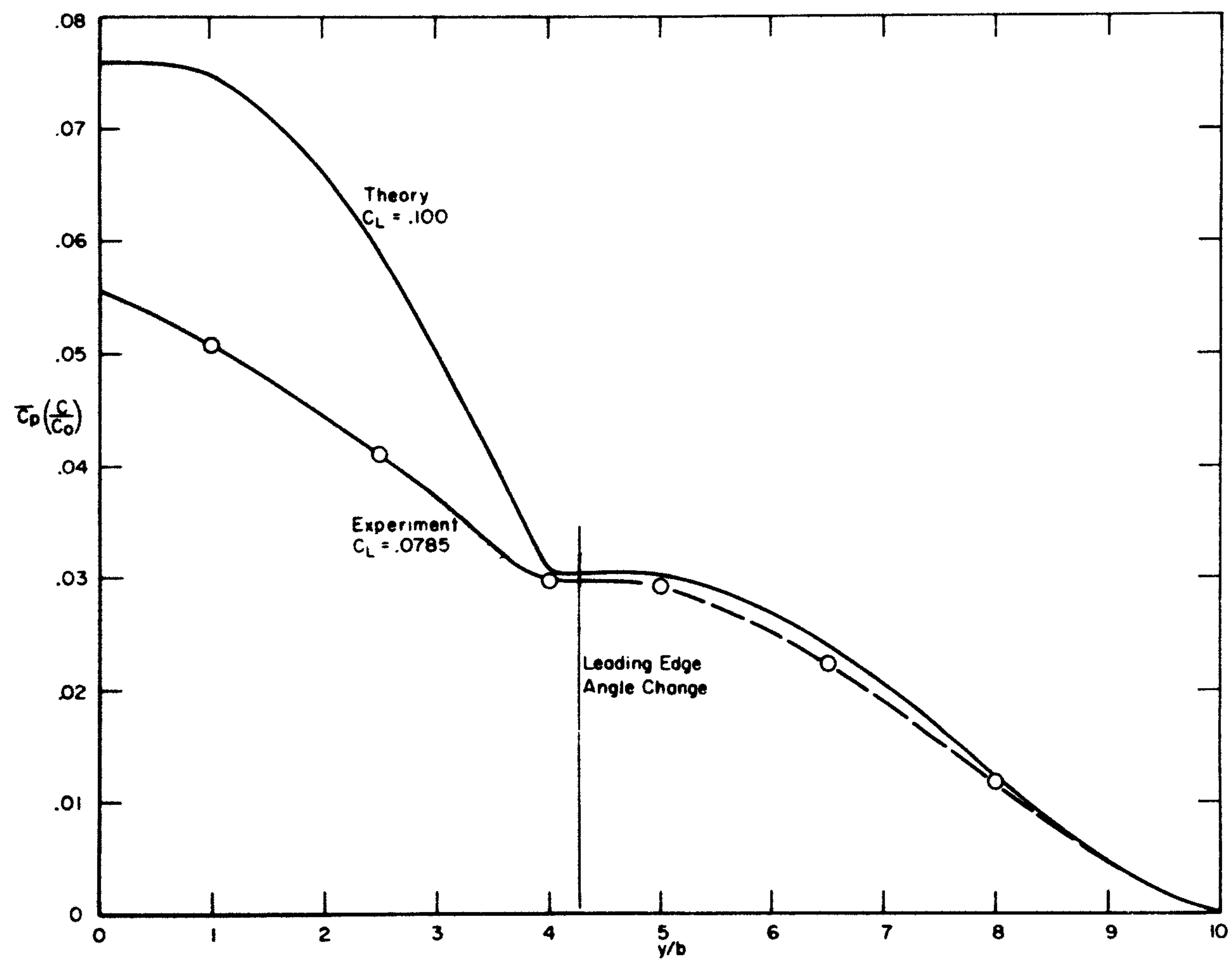


Figure 41b. Comparison of the theoretical and measured spanwise loadings on the warped double-delta wing

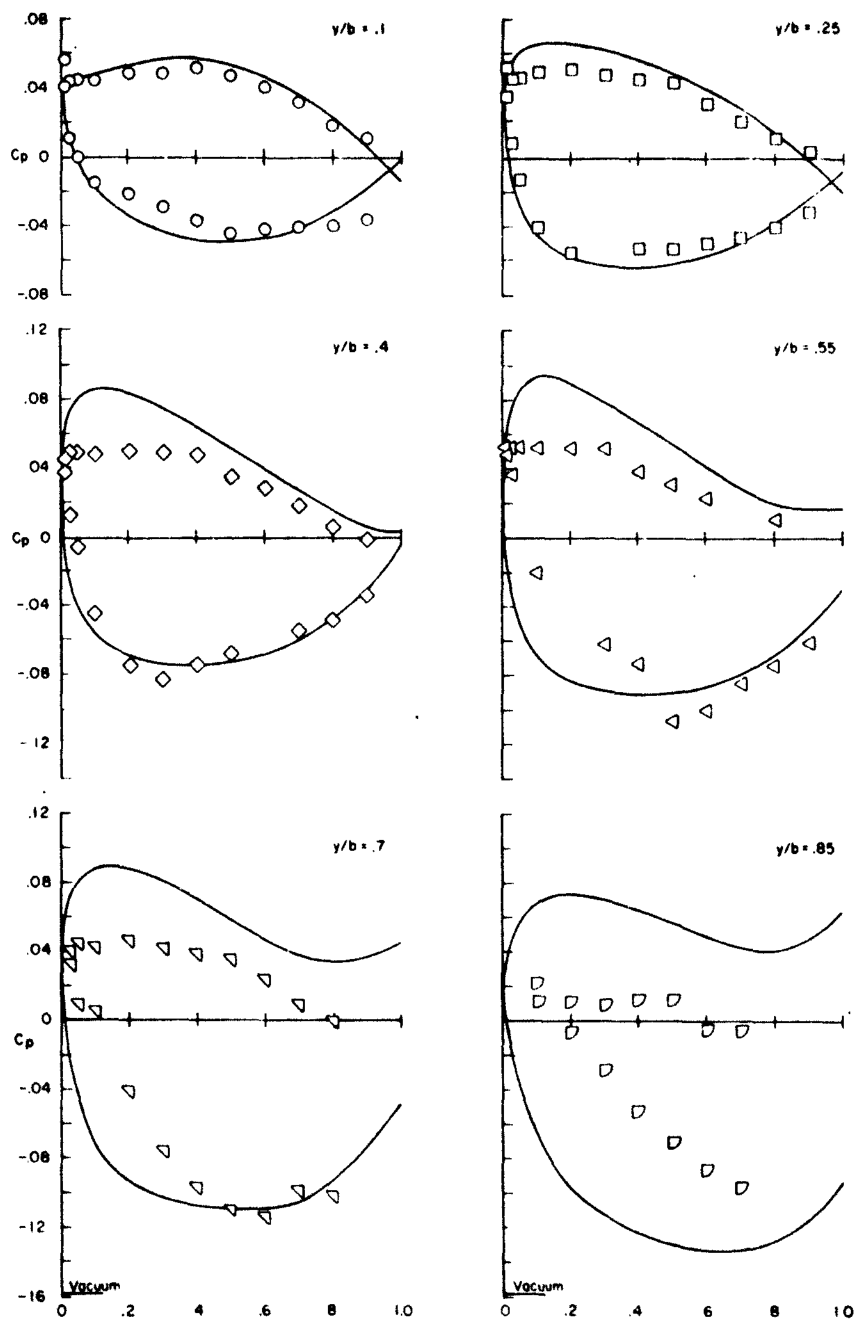


Figure 42. Predicted and measured pressure distribution on warped arrow wing at 0° angle of attack

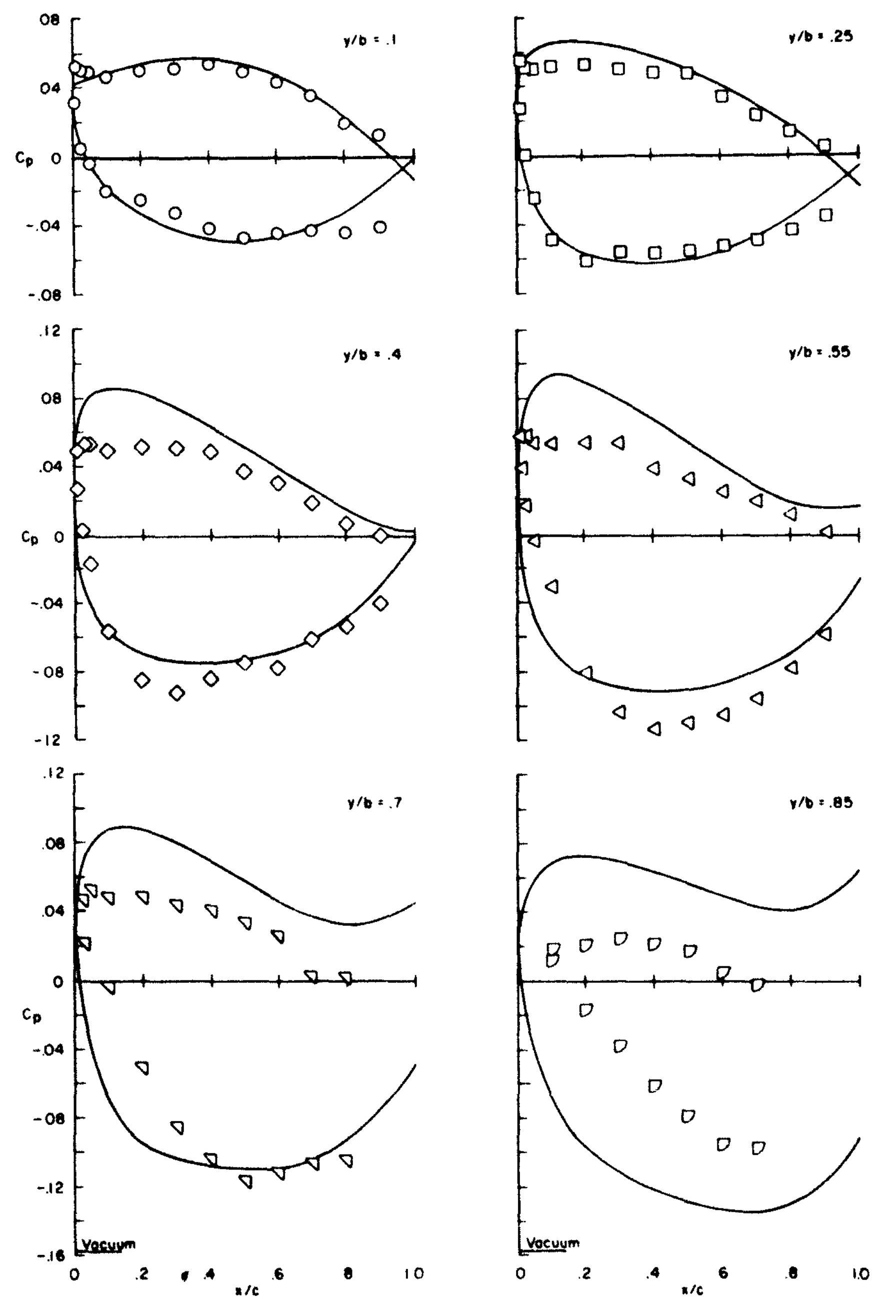


Figure 43. The predicted pressure distribution at 0° angle of attack and that measured at 0.5° for the warped arrow wing

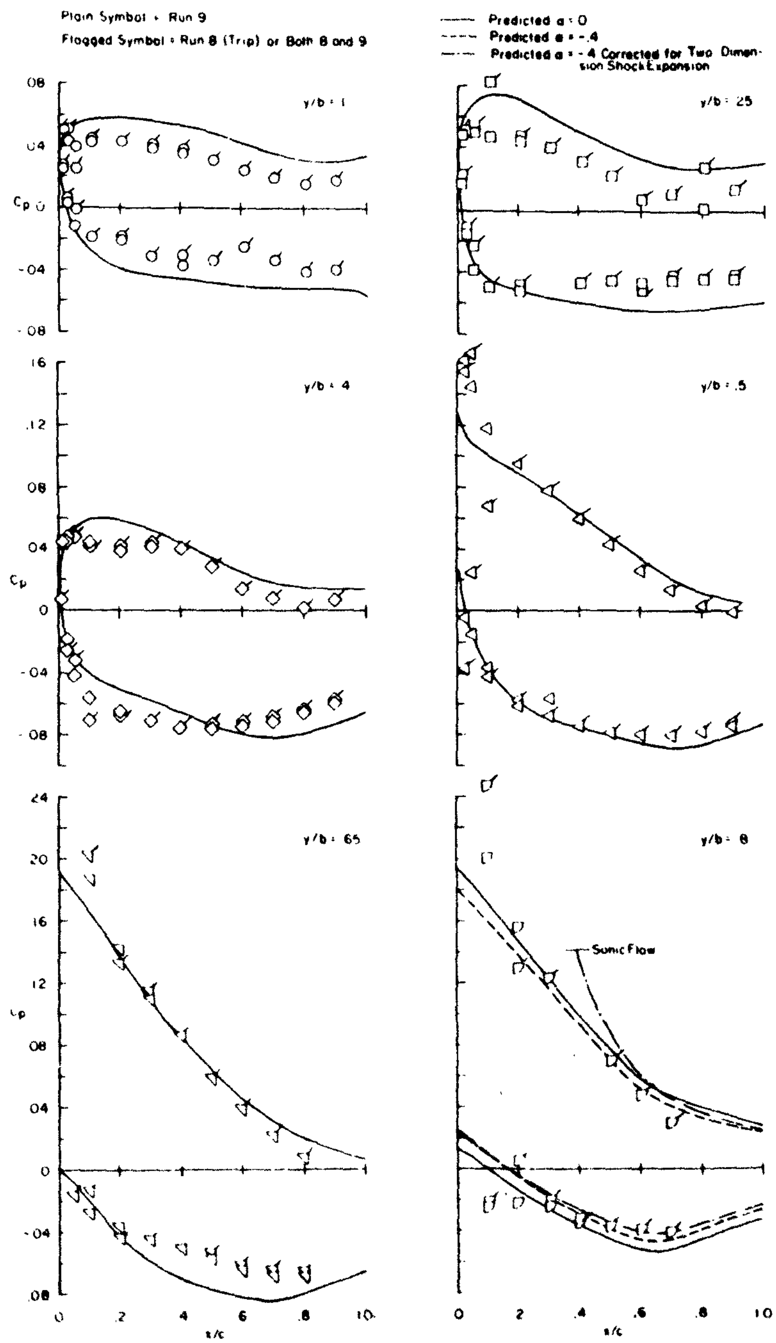


Figure 44. The predicted and measured pressure distributions for the warped double-delta wing at 0° angle of attack

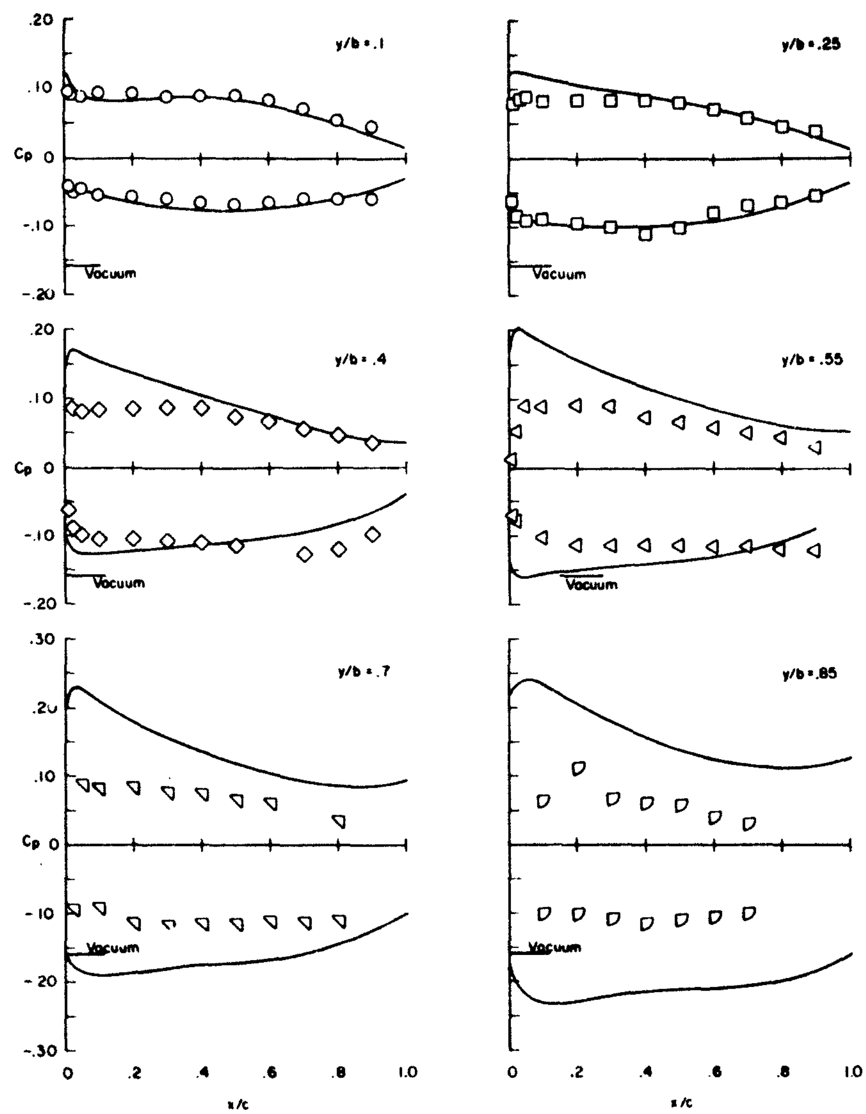


Figure 45. Predicted and measured pressure distributions for the warped arrow wing at 5° angle of attack

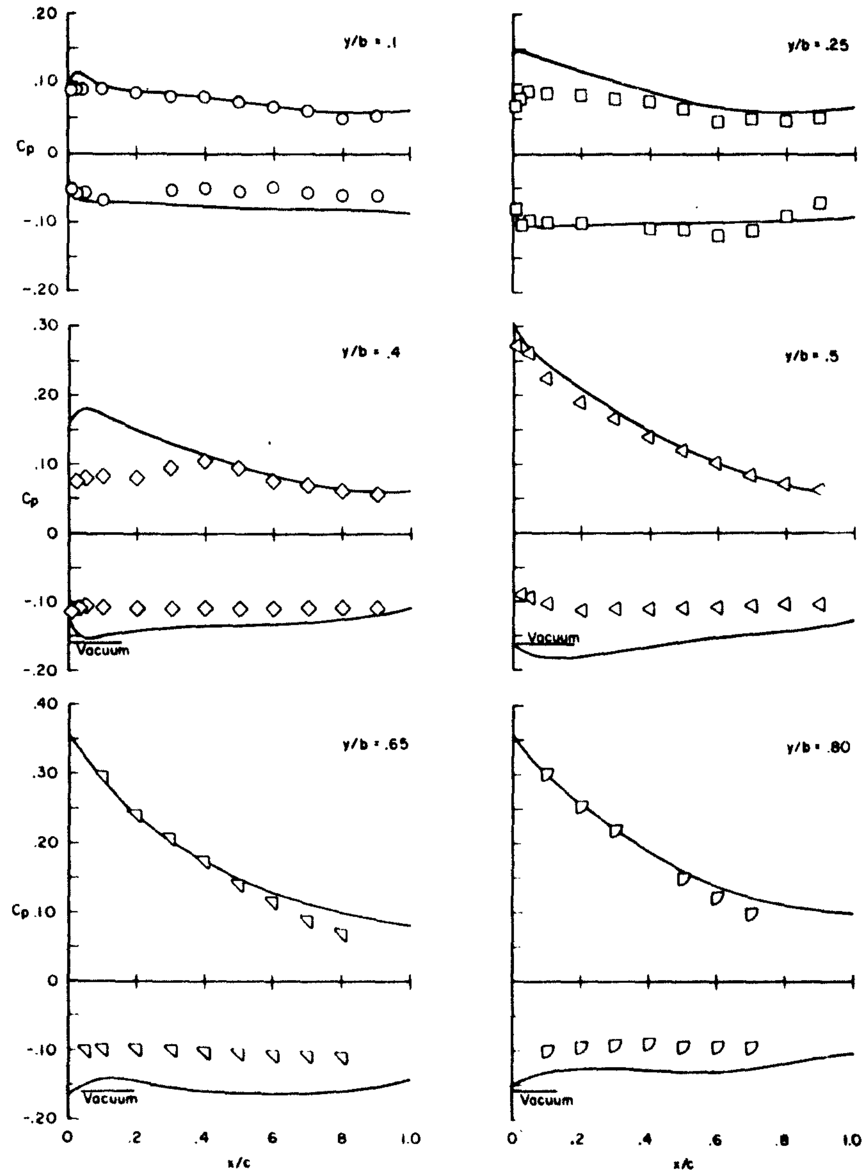


Figure 46. Predicted and measured pressure distributions for the warped double-delta wing at 5° angle of attack

TABLE I

Comparison of Optimum Four, Six, and Eight Term Polynomial Loadings for the Double Delta Planform used in the Wind Tunnel Test.

$$N = 4, \quad C_D = 0.593\, C_L^2$$

$$\frac{\ell}{q} = 1.672 - 2.444\,\bar{x} + 2.821\,|\bar{y}| - 1.108\,\bar{y}^2$$

$$N = 6, \quad C_D = 0.575\, C_L^2$$

$$\frac{\ell}{q} = 2.934 - 8.759\,\bar{x} + 4.984\,|\bar{y}| - 1.479\,\bar{y}^2 + 6.017\,\bar{x}^2 - 2.406\,\bar{x}\,|\bar{y}|$$

$$N = 8, \quad C_D = 0.570\, C_L^2$$

$$\frac{\ell}{q} = 3.377 - 12.629\,\bar{x} + 5.314\,|\bar{y}| - 0.0153\,\bar{y}^2 + 14.519\,\bar{x}^2 - 3.864\,\bar{x}\,|\bar{y}| - 5.264\,\bar{x}^3 - 0.524\,|\bar{y}^3|$$

TABLE II

The Camber Ordinates of the Arrow Wing

	x	alpha	z ℄	z upper	z lower
y = 0	0.0000	-0.00104	0.00000	0.00000	0.00000
	1.0000	0.01488	-0.00646	0.17462	-0.18754
	2.0000	0.03372	-0.03069	0.21831	-0.27970
	3.0000	0.05232	-0.07381	0.22519	-0.37281
	4.0000	0.06941	-0.13482	0.20332	-0.47297
	5.0000	0.08461	-0.21200	0.15690	-0.58090
	6.0000	0.09787	-0.30340	0.08889	-0.69569
	7.0000	0.10920	-0.40710	0.00155	-0.81574
	8.0000	0.11857	-0.52114	-0.10317	-0.93911
	9.0000	0.12592	-0.64356	-0.22346	-1.06365
	10.0000	0.13121	-0.77229	-0.35745	-1.18714
	11.0000	0.13439	-0.90527	-0.50314	-1.30740
	12.0000	0.13546	-1.04037	-0.65833	-1.42241
	13.0000	0.13444	-1.17549	-0.82058	-1.53040
	14.0000	0.13134	-1.30855	-0.98718	-1.62992
	15.0000	0.12615	-1.43747	-1.15505	-1.71989
	16.0000	0.11887	-1.56015	-1.32074	-1.79957
	17.0000	0.10946	-1.67450	-1.48080	-1.86820
	18.0000	0.09794	-1.77837	-1.63257	-1.92417
	19.0000	0.08435	-1.86969	-1.77179	-1.96759
	20.0000	0.06871	-1.94639	-1.89639	-1.99639
	21.0000	0.05088	-2.00639	-2.00429	-2.00849
y = 1	4.7046	-0.04350	0.00000	0.00000	0.00000
	5.0000	-0.02187	0.00955	0.10329	-0.08419
	6.0000	0.02813	0.00404	0.18887	-0.18079
	7.0000	0.05850	-0.04032	0.19958	-0.28021
	8.0000	0.07987	-0.11002	0.17044	-0.39049
	9.0000	0.09610	-0.19836	0.11245	-0.50918
	10.0000	0.10841	-0.30092	0.03148	-0.63333
	11.0000	0.11729	-0.41405	-0.06847	-0.75962
	12.0000	0.12309	-0.53448	-0.18427	-0.88469
	13.0000	0.12615	-0.65931	-0.31328	-1.00535
	14.0000	0.12668	-0.78593	-0.45301	-1.11885
	15.0000	0.12478	-0.91187	-0.60087	-1.22287
	16.0000	0.12044	-1.03468	-0.75380	-1.31556
	17.0000	0.11368	-1.15194	-0.90825	-1.39562
	18.0000	0.10459	-1.26126	-1.06006	-1.46246
	19.0000	0.09330	-1.36039	-1.20514	-1.51564
	20.0000	0.07981	-1.44713	-1.33977	-1.55448
	21.0000	0.06401	-1.51923	-1.45978	-1.57869
	22.0000	0.04606	-1.57442	-1.56286	-1.58597
	22.2046	0.04223	-1.58345	-1.58170	-1.58520
y = 2	9.4093	-0.10093	0.00000	0.00000	0.00000
	10.0000	-0.03774	0.03951	0.15371	-0.07470
	11.0000	0.02324	0.04347	0.22338	-0.13644
	12.0000	0.05822	0.00141	0.22417	-0.22135
	13.0000	0.08152	-0.06918	0.18334	-0.32169
	14.0000	0.09755	-0.15923	0.11219	-0.43065
	15.0000	0.10801	-0.26242	0.01735	-0.54219
	16.0000	0.11405	-0.37378	-0.09657	-0.65100
	17.0000	0.11642	-0.48930	-0.22581	-0.75279
	18.0000	0.11546	-0.60551	-0.36662	-0.84440
	19.0000	0.11132	-0.71916	-0.51455	-0.92377
	20.0000	0.10420	-0.82715	-0.66418	-0.99013
	21.0000	0.09438	-0.92666	-0.80986	-1.04346
	22.0000	0.08194	-1.01505	-0.94615	-1.08395
	23.0000	0.06676	-1.08961	-1.06861	-1.11061
	23.4093	0.06004	-1.11556	-1.11416	-1.11696
y = 3	14.1139	-0.14894	0.00000	0.00000	0.00000
	15.0000	-0.04618	0.08176	0.19954	-0.03603
	16.0000	0.01582	0.09376	0.25877	-0.07125
	17.0000	0.05128	0.05876	0.25255	-0.13503
	18.0000	0.07368	-0.00453	0.20370	-0.21277
	19.0000	0.08780	-0.08586	0.12248	-0.29421
	20.0000	0.09561	-0.17803	0.01559	-0.37166
	21.0000	0.09839	-0.27541	-0.11064	-0.44017
	22.0000	0.09695	-0.37340	-0.24866	-0.49814
	23.0000	0.09166	-0.46802	-0.38966	-0.54637
	24.0000	0.08293	-0.55558	-0.52512	-0.58603
	24.6139	0.07591	-0.60441	-0.60336	-0.60546
y = 4	18.8185	-0.17608	0.00000	0.00000	0.00000
	19.0000	-0.15705	0.03031	0.07598	-0.01537
	20.0000	-0.04825	0.12889	0.23604	0.02174
	21.0000	0.00753	0.14616	0.28018	0.01214
	22.0000	0.04032	0.12099	0.26037	-0.01840
	23.0000	0.05975	0.07002	0.19272	-0.05268
	24.0000	0.07088	0.00416	0.09063	-0.08230
	25.0000	0.07513	-0.06940	-0.02949	-0.10931
	25.8185	0.07450	-0.13106	-0.13036	-0.13176
y = 5	23.5231	-0.18444	0.00000	0.00000	0.00000
	24.0000	-0.14459	0.08291	0.13170	0.03411
	25.0000	-0.04697	0.17219	0.24223	0.10215
	26.0000	0.00128	0.19258	0.24059	0.14456
	27.0000	0.02826	0.17645	0.17790	0.17499
	27.0231	0.02853	0.17579	0.17614	0.17544
y = 6	28.2278	-0.21612	0.00000	0.00000	0.00000

TABLE III

The Camber Ordinates of the Double Delta Wing

	x	alpha	z ℄	z upper	z lower
y = 0	0.0000	-0.00200	0.00000	0.00000	0.00000
	1.0000	0.01529	-0.00630	0.17006	-0.18267
	2.0000	0.03391	-0.03098	0.21152	-0.27347
	3.0000	0.05065	-0.07348	0.21745	-0 36440
	4.0000	0.06460	-0.13134	0.19715	-0.45984
	5.0000	0 07575	-0.20174	0.15580	-0.55928
	6 0000	0.08442	-0.28202	0.09696	-0.56100
	7.0000	0.09089	-0.36985	0.02322	-0.76291
	8.0000	0.09542	-0.46315	-0.06344	-0.86286
	9 0000	0.09823	-0.56011	-0.16139	-0.95883
	10.0000	0.09961	-0.65914	-0.26922	-1.04906
	11.0000	0.09985	-0.75895	-0.38564	-1.13226
	12.0000	0.09928	-0.85857	-0.50946	-1.20769
	13.0000	0.09823	-0.95736	-0.63946	-1.27525
	14.0000	0.09695	-1.05495	-0.77438	-1.33552
	15.0000	0.09567	-1.15125	-0.91272	-1.38978
	16.0000	0.09459	-1.24635	-1 05276	-1.43994
	17.0000	0.09397	-1.34058	-1.19488	-1.48628
	18.0000	0.09418	-1.43457	-1.33677	-1.53237
	19.0000	0.09568	-1.52938	-1.47948	-1.57928
	20.0000	0.09873	-1.62645	-1.62445	-1.62845
	20.0000	0.09873	-1.62645	-1.62445	-1.62845
y = 1	4.7046	-0.01734	0.00000	0.00000	0.00000
	5.0000	0.00517	0.00163	0.09035	-0.08708
	6.0000	0.04731	-0.02785	0.14706	-0.20275
	7.0000	0.06592	-0.08547	0.14116	-0.31211
	8.0000	0.07700	-0 15730	0.10660	-0.42119
	9.0000	0.08458	-0.23834	0.05225	-0.52892
	10.0000	0.08936	-0.32552	-0.01769	-0.63335
	11.0000	0.09183	-0.41628	-0.10057	-0.73198
	12.0000	0.09275	-0.50866	-0.19473	-0.82259
	13.0000	0.09280	-0.60149	-0.29923	-0.90374
	14.0000	0.09237	-0.69410	-0.41330	-0.97491
	15.0000	0 09163	-0.78612	-0.53585	-1.03640
	16.0000	0.09084	-0.87734	-0.66523	-1 08946
	17.0000	0.09045	-0.96793	-0.79931	-1.13655
	18.0000	0.09096	-1.05855	-0.93697	-1 18012
	19.0000	0.09249	-1.15019	-1 07651	-1.22386
	20.0000	0.09515	-1.24388	-1.21810	-1.26965
	20.5051	0.09754	-1.29249	-1.29091	-1.29407
y = 2	9.4093	-0.04301	0.00000	0.00000	0.00000
	10.0000	0.01416	0.00617	0.10933	-0.09699
	11.0000	0.04874	-0.02870	0.13351	-0.19091
	12.0000	0.06232	-0.08493	0.11404	-0.28390
	13.0000	0.07003	-0.15149	0.07022	-0.37320
	14.0000	0.07382	-0.22367	0.00802	-0.45537
	15.0000	0.07543	-0.29840	-0.06985	-0.52695
	16.0000	0.07636	-0.37432	-0.16237	-0.58627
	17.0000	0.07694	-0.45100	-0.26835	-0.63366
	18.0000	0.07739	-0.52815	-0.38500	-0.67130
	19.0000	0.07854	-0.60602	-0.50857	-0.70347
	20.0000	0.08072	-0.68559	-0.63604	-0.73515
	21.0000	0.08366	-0.76760	-0.76595	-0.76926
	21.0000	0.08371	-0.76847	-0.76730	-0.76963
y = 3	14.1139	-0.05630	0.00000	0.00000	0.00000
	15.0000	0.01118	0.01245	0.10984	-0.08494
	16.0000	0.03104	-0.01036	0.12284	-0.14357
	17.0000	0.03871	-0.04982	0.10183	-0.19347
	18.0000	0.04104	-0.08507	0.05551	-0.2[illegible]765
	19.0000	0.03880	-0.12634	-0.01133	-0.24135
	20 0000	0.03449	-0.16296	-0.08972	-0.23620
	21.0000	0.03011	-0.19538	-0.16995	-0 22081
	21.5154	0.02944	-0.21048	-0.20974	-0.21122
y = 4	17.1129	0.04382	0 00000	0.00000	0.00000
	18 0000	0.07328	-0.05718	0.02015	-0.13451
	19 0000	0.07301	-0.13044	-0.03267	-0.22822
	20.0000	0.06938	-0.20210	-0.11488	-0.28932
	21.0000	0.06427	-0.26887	-0.21958	-0.31815
	22 0000	0.05553	-0.32921	-0.32774	-0.33069
	22.0205	0.05531	-0.33035	-0.32986	-0.33084
y = 5	18.8449	0 09786	0.00000	0.00000	0.00000
	10.0000	0.09940	-0.01534	0.01466	-0.04534
	20.0000	0.08949	-0.11097	-0.04038	-0.18157
	21.0000	0.06910	-0.19040	-0.12472	-0.25608
	22 0000	0.04747	-0.24865	-0.22310	-0.27419
	22 5257	0.03946	-0.27115	-0.27079	-0.27152
y = 6	20.5770	0.10705	0.00000	0.00000	0.00000
	21.0000	0.09353	-0.04247	-0.00457	-0.08037
	22.0000	0.05692	-0.11799	-0 07386	-0.16213
	23.0000	0 01919	-0.15598	-0.15426	-0.15770
	23.0308	0.01801	-0.15655	-0.15631	-0.15680
y = 7	22.3090	0.08122	0.00000	0.00000	0.00000
	23.0000	0.04077	-0.04211	-0.01956	-0.06467
	23.5360	0.00924	-0.05555	-0.05543	-0.05567
y = 8	24 0411	0.01967	0.00000	0.00000	0.00000
	24.0411	0.01956	0.00000	0.00000	0.00000

TABLE IV

Run Schedule

First Test

Run No.	Wing	P_o	Angle of Attack (Deg.)	Type Test	Type Data	Wing Gap*	Boundary Layer Trip	Dew Point	Comments
1	Flat Arrow	8-30-7	2	Flow Visualization	Photos	010	None	--	Gap at leading edge of foot causing separation.
2	"	"	4	"	"	"	"	11	
3	"	"	0	"	"	"	"	-18	Reduced gap
4	"	"	6	"	"	"	"	-28	
5	"	30	-2, -1	Pressure	Manometer Photos + Force Data	"	"	-12	Developed leak in manometer ref.
6	"	"	-2, -1, 0 1, 2, 3, 4, 5, 6, 7 9, 2	"		"	"	-13	Repeat of 5
7	"	"	+2	"	"	"	2	-18	Trip did not seem effective
8	"	"	2, -2, 0, 4 6, 9	"	"	"	4	-27	Doubled trip size
9	"	"	2	"	Manometer Photos	Sealed	None	-30	Data indicated separation due to flow from gap
10	"	"	024	"	Manometer +Force	010	"	-28	Reduced gap to .005
11	"	"	"	"	Manometer Photos	Sealed	"	--	
12	"	"	-2, -1, 0, 1 2, 3, 4, 5, 6, 7, 8, 9	Force	Force Data only	010	0	--	
13	"	"	"	"	"	"	4	--	
14	"	"	"	"	"	"	8	-33	
15	Flat Double Delta	8-30-7	2	Flow Visualization	Photos	"	0	-30	
16	"	"	4	"	"	"	"	--	
17	"	30	-2, -1, 0	Pressure	Manometer Photos + Force	"	"	-24	Cooler developed leak Dewpoint α = 5 was +5°
18	"	"	3, 4, 5, 6, 7, 9	"	"	"	"	-10	Repeat of 18
19	"	"	0, 2, 4, 6	"	"	"	4	-23	
20	"	"	"	"	Manometer + Photos only	.002	0	-34	
21	"	20	-6, -5, -4, -3 -2, -1, 0 1, 2, 3, 4, 5, 6 7, 8, 9	Force	Force	010	4	-26	Data taken to discover effect of metal chips in balance
22	"	"	-6, -5, -4, -3 -2, -1, 0, 1, 2, 4, 6, 8	"	"	"	"	-30	
23	"	30	-6, -5, -4, -3, -2	"	"	"	"	--	

* Gap between wing root and splitter plate

TABLE IV

Run Schedule

Second Test

Run	Wing	P_0	Angle of Attack	Type Test	Type Data	Wing Gap	Boundary Layer Trip	Dew Point	Comments
1	Warped Arrow	5-30-5	0	Flow Visualization	Photos	.010	None	--	
2	"	30	-5, -2, -1, 0, 1/2, 1, 2, 5	Pressure	Manometer Photos and Force Data	"	"	-37° to -10°	
3	"	"	-2, -1, 0, 1, 2, 5	"	"	"	3	-41 to -42	
4	"	"	-10 to +5 1° intervals	Force	Force	"	"	-45	
5	"	"	"	"	"	"	None	--	
6	Warped Double delta	"	-5, -2, -1, 0, +1, +2, +2, +5	Pressure	Manometer Photos and Force	"	"	-33 to +10	Dew point was found to be +10 at $\alpha = +2°$. Repeated data at $\alpha = 2°$
7	"	"	-5, -2, -1, 0, 1, 2, 5	"	"	"	3	-40	
8	"	"	-10 to +5 1° intervals	Force	"	"	"	"	
9	"	"	"	"	"	"	None	-60	
10	"	5-20-5	0	Flow Visualization	Photos	"	"	--	Removed wing for photos

TABLE V

Drag vs. Reynolds Number for Flat Arrow Wing

R $\times 10^{-6}$	Run	5	6	10	12	7	8	13	14
	α	0	0	0	0	0	0	0	0
	Trip thickness	← No Trip →				2	4	4	8
2.10		--	--	--	--	--	.00606	--	--
2.62		.00648	.00607	.00608	.00597	.00638	--	.00618	.00679
3.16		.00618	--	.00584	.00583	.00609	.00609	.00618	.00678
3.68		.00603	.00586	.00573	.00579	.00596	.00602	.00625	.00669
4.20		.00592	.00576	.00585	.00572	.00599	.00601	.00625	.00656
4.72		.00584	.00572	.00572	.00566	.00594	.00602	.00618	.00663
5.26		.00581	.00566	.00566	.00571	.00602	.00622	.00618	.00653
5.78		.00580	.00562	.00561	.00561	.00590	--	.00599	.00658
6.30		.00582	.00558	.00549	.00558	.00588	.00618	.00605	.00648
6.82		.00574	.00562	.00554	.00554	.00586	.00618	.00599	.00645
7.36		.00560	.00562	.00554	.00559	.00587	.00614	.00602	.00646
7.88		--	.00570	.00559	.00562	.00590	.00614	.00607	.00645

Accuracy = ± .0001 at max Re
± .0003 at min Re

TABLE VI

Drag vs. Reynolds Number - Flat Double Delta Wing

R	Run	15	16	18	19	21	23
	α	2	4	0	0	0	0
$\times 10^{-6}$	Trip thickness	← No Trip →			4	4	4
2.0		--	--	.00685	.00800	.00848	.00810
2.5		.00685	.00720	.00662	.00776	.00765	.00778
3.0		.00666	.00714	.00648	.00780	.00797	.00772
3.5		.00653	.00702	.00652	.00783	.00768	.00776
4.0		.00649	.00698	.00656	.00784	.00771	.00780
4.5		.00652	.00698	.00659	.00775	.00774	.00776
5.0		.00657	.00685	.00657	.00788	.00771	.00778
5.5		.00665	.00669	.00660	.00782	.00763	.00769
6.0		.00676	.00661	.00657	.00765	.00766	.00767
6.5		.00680	.00654	.00657	.00772	.00764	.00766
7.0		.00680	.00648	.00660	.00774	.00770	.00768
7.5		.00689	.00643	.00662	.00767	.00768	.00770

Accuracy = ±.0001 at max Re
±.0003 at min Re

TABLE VII

Forces vs. Reynolds Number for the Warped Arrow Wing

	Run 1 No trip (0)				Run 4 With trip (3)			
$R \times 10^{-6}$	C_m	C_L	C_D	L/D	C_m	C_L	C_D	L/D
1.58	0.0050	0.0755	0.0118	6.42	--	--	--	--
2.10	0.0047	0.0750	0.0119	6.30	--	--	--	--
2.62	0.0044	0.0750	0.0118	6.33	0.0041	0.0774	0.0131	5.90
3.16	0.0041	0.0768	0.0120	6.38	0.0039	0.0795	0.0131	6.05
3.68	0.0039	0.0766	0.0120	6.40	0.0037	0.0779	0.0128	6.08
4.20	0.0038	0.0779	0.0122	6.39	0.0035	0.0782	0.0127	6.16
4.72	0.0036	0.0771	0.0121	6.37	0.0034	0.0781	0.0126	6.22
5.26	0.0035	0.0777	0.0121	6.40	0.0033	0.0792	0.0127	6.25
5.78	0.0034	0.0783	0.0122	6.42	0.0032	0.0789	0.0126	6.26
6.30	0.0033	0.0778	0.0121	6.42	0.0031	0.0790	0.0125	6.29
6.82	0.0033	0.0776	0.0122	6.39	0.0031	0.0784	0.0125	6.29
7.36	0.0032	0.0780	0.0122	6.41	0.0031	0.0787	0.0124	6.33
7.88	0.0032	0.0783	0.0122	6.42	0.0030	0.0784	0.0124	6.33

TABLE VIII

Forces vs. Reynolds Number for the Warped Double Delta Wing

$R \times 10^{-6}$	Run 9 No trip (0) C_m	C_L	C_D	L/D	Run 8 With trip (3) C_m	C_L	C_D	L/D
1.50	0.00194	0.0702	0.0126	5.58	0.00238	0.0732	0.0135	5.43
2.00	0.00145	0.0741	0.0126	5.87	0.00178	0.0772	0.0134	5.77
2.50	0.00198	0.0754	0.0125	6.01	0.00134	0.0792	0.0133	5.96
3.00	0.00182	0.0760	0.0124	6.12	0.00112	0.0784	0.0131	6.00
3.50	0.00057	0.0762	0.0124	6.15	0.00089	0.0782	0.0130	6.01
4.00	0.00050	0.0775	0.0124	6.24	--	--	--	--
4.25	--	--	--	--	0.00068	0.0786	0.0130	6.05
4.50	0.00040	0.0770	0.0123	6.25	--	--	--	--
5.00	0.00031	0.0780	0.0123	6.32	0.00054	0.0788	0.0129	6.11
5.50	0.00028	0.0782	0.0123	6.36	0.00049	0.0791	0.0129	6.12
6.00	0.00019	0.0781	0.0122	6.38	0.00041	0.0794	0.0129	6.16
6.50	0.00014	0.0775	0.0121	6.38	0.00038	0.0786	0.0128	6.14
7.00	0.00010	0.0774	0.0121	6.39	0.00035	0.0786	0.0128	6.15
7.50	0.00012	0.0780	0.0121	6.44	0.00033	0.0784	0.0127	6.16

TABLE IX

Force Data for the Flat Arrow Wing

Run 5 No trip (0)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
-51.20000	-51.23800	51.23223	49.92192	-49.43815	48.55446	-47.19227	-49.43547	48.73593
-51.10000	-51.13800	51.22297	49.74557	-49.25290	48.53318	-46.89726	-49.25155	48.59394
46.00000	-50.38000	51.13916	50.46561	-48.75339	48.55278	-47.16663	-48.74971	48.55776
46.00000	-50.38000	-52.17152	51.79198	-47.10264	47.20532	-46.38454	-47.10128	47.20599

Run 6 No trip (0)

46.00000	-50.35000	-52.16816	-52.13200	47.10310	-47.34242	-46.64090	47.10100	-47.34304
-51.10000	-51.13500	51.22748	49.97335	-49.24907	48.54016	-47.11536	-49.24773	48.59869
46.00000	-50.35000	50.34357	50.38045	-48.78011	48.55269	-47.14100	-48.77672	48.55744
51.10000	50.65000	51.33650	-50.56767	49.10888	48.54174	-47.29481	49.10826	48.55406
51.20000	51.16500	51.32267	-50.31870	49.27854	48.53708	-47.42299	49.27688	48.61706
51.30000	51.26500	51.27545	-49.85753	49.47067	48.53659	-47.19227	49.46769	48.75361
51.40000	51.36500	51.26391	48.41473	49.64888	48.52536	46.12818	49.64422	48.93736
51.50000	51.46500	51.25422	50.17087	49.83475	48.51781	47.67935	49.82781	49.11928
51.60000	51.56500	51.25405	50.28526	50.10095	48.52017	48.13715	49.99949	49.15115
51.70000	51.66500	51.24341	50.37548	50.11970	48.52639	48.21406	50.11829	49.19090
51.90000	51.86500	51.22541	50.55813	50.15576	48.53833	48.41402	50.15318	49.28747
51.20000	51.16500	51.26800	-49.46235	49.29092	48.53749	-46.64090	49.28925	48.62104
46.00000	-50.35000	-52.16881	-52.13200	-47.10287	47.27387	46.64090	-47.10120	47.27449

Run 8 With trip (4)

46.00000	-50.27000	-51.73302	50.84350	-47.63812	-46.36391	-46.25636	-47.63829	-46.33381
51.20000	51.17300	51.30503	-50.22854	49.28249	48.56806	-47.30763	49.28065	48.65309
-51.20000	-51.22700	51.23722	50.12415	-49.43381	48.57517	-47.25636	-49.43119	48.74655
46.00000	-50.27000	51.14502	50.58806	-48.73435	48.59054	-47.20509	-48.73156	48.59400
51.40000	51.37300	51.26794	49.74990	49.64593	48.54926	47.23072	49.64099	48.96829
51.60000	51.57300	51.25188	50.29434	50.10058	48.53033	48.14100	49.99548	49.15318
51.90000	51.87300	51.22450	50.54981	50.15567	48.53488	48.40761	50.15306	49.28914
46.00000	-50.27000	-51.73768	50.84350	47.63710	47.34487	46.25636	47.63872	47.34186

Run 10 No trip (0)

46.00000	-50.27000	51.52693	51.38268	-47.42205	-45.13985	-46.76908	-47.42205	44.59177
46.00000	-50.27000	50.62625	50.15896	-48.67918	48.55302	-46.51272	-48.67657	48.55622
51.20000	51.17300	51.30114	-50.27594	49.29247	48.52040	-47.38454	49.29077	48.60847
51.40000	51.37300	51.26342	49.72843	49.66499	48.50190	47.23072	49.66032	48.93343
46.00000	-50.27000	-51.21313	51.25801	47.62472	47.37911	46.76908	47.62650	47.37616
46.00000	-50.27000	-52.67291	-52.25537	-46.63131	-46.34485	46.76908	-46.63293	-46.34187

TABLE IX

Force Data for the Flat Arrow Wing (concl'd)

Run 12 No trip (0)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.26000	-51.26558	51.12396	-47.43431	-45.14391	-46.25636	-47.43431	44.53090
46.00000	-50.26000	-51.1061?	50.19507	-48.55381	48.56029	-46.51272	-48.55127	48.56280
-51.20000	-51.22600	51.23873	-49.26637	-49.40440	48.54187	46.51272	-49.40195	48.70093
-51.10000	-51.12600	51.18670	-49.46953	-49.22950	48.54081	46.51272	-49.22826	48.59115
46.00000	-50.26000	-51.10613	50.19507	-48.55381	48.56029	-46.51272	-48.55127	48.56280
51.10000	50.74000	51.36131	-50.20380	49.13190	48.54936	-47.12818	49.13118	48.56635
51.20000	51.17400	51.31015	-50.13891	49.30986	48.53126	-47.20509	49.30811	48.62510
51.30000	51.27400	51.28012	-49.32728	49.49331	48.53391	-46.76908	49.49019	48.76910
51.40000	51.37400	51.26088	50.10287	49.68020	48.51612	47.33327	49.67539	48.95868
51.50000	51.47400	51.25273	50.23173	49.85943	48.50834	47.94853	49.85229	49.12168
51.60000	51.57400	51.24352	50.32848	50.10487	48.50091	48.16407	50.10385	49.15472
51.70000	51.67400	51.23639	50.39915	50.12272	48.50339	48.23329	50.12128	49.19401
51.80000	51.77400	51.23989	50.49183	50.14009	48.49201	48.32814	50.13815	49.23742
51.90000	51.87400	51.22438	50.55998	50.15861	48.49129	48.42300	50.15603	49.28956
46.00000	-50.26000	-50.75374	12.00000	-48.54363	48.56375	12.00000	-48.54107	48.56622

Run 13 With trip (4)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.16000	-51.57764	12.00000	-47.41512	46.50039	12.00000	-47.41498	46.51198
46.00000	-50.16000	51.47785	50.32954	-48.32875	48.60731	-46.51272	-48.32705	48.60823
-51.20000	-51.21600	51.28402	-49.27636	-49.38980	48.58520	46.51272	-49.38732	48.73169
-51.10000	-51.11600	51.28448	-49.25314	-49.21287	48.59792	46.25636	-49.21161	48.64090
46.00000	-50.16000	51.55064	50.37334	-48.29041	48.60744	-46.51272	-48.28872	48.60825
51.10000	50.84000	51.27717	-50.15560	49.13819	48.59927	-47.10254	49.13730	48.61946
51.20000	51.18400	51.27246	-49.66670	49.32280	48.58139	-47.10254	49.32077	48.68474
51.30000	51.28400	51.25614	12.00000	49.50485	48.56343	12.00000	49.50144	48.81288
51.40000	51.38400	51.24020	50.12456	49.69135	48.55247	47.41018	49.68610	49.10142
51.50000	51.48400	51.23594	50.24151	49.86917	48.54466	47.99981	49.86148	49.12760
51.60000	51.58400	51.23588	50.33106	50.10568	48.54402	48.16663	50.10458	49.16165
51.70000	51.68400	51.23414	50.40454	50.12375	48.54658	48.23841	50.12222	49.20164
51.80000	51.78400	51.22690	50.50011	50.14208	48.54237	48.33840	50.14001	49.24753
51.90000	51.88400	51.22022	50.57250	50.15984	48.53797	48.43581	50.15712	49.29880
46.00000	-50.16000	51.15721	50.25880	-48.41806	48.60702	-46.51272	-48.41636	48.60818

Run 14 With trip (8)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.19000	-51.74713	12.00000	-47.81060	46.14452	12.00000	-47.81054	46.17143
46.00000	-50.19000	-49.73952	50.12301	-48.43982	48.64807	-46.25636	-48.43766	48.64953
-51.20000	-51.21900	51.25750	-49.13526	-49.39824	48.61920	46.25636	-49.39558	48.77093
-51.10000	-51.11900	51.24581	49.24463	-49.22028	48.63538	-46.25636	-49.21892	48.68099
46.00000	-50.19000	51.14817	50.12370	-48.43735	48.64465	-46.25636	-48.43521	48.64610
51.10000	50.81000	51.34373	-50.24398	49.13219	48.63677	-47.15382	49.13127	48.65539
51.20000	51.18100	51.29810	-49.85675	49.31398	48.61538	-47.12818	49.31188	48.71424
51.30000	51.28100	51.26540	12.00000	49.50088	48.59415	12.00000	49.49737	48.83897
51.40000	51.38100	51.25216	50.13378	49.68394	48.57622	47.43581	49.67860	49.10294
51.50000	51.48100	51.24539	50.24752	49.86982	48.56867	48.10254	49.86198	49.12960
51.60000	51.58100	51.24021	50.32719	50.10529	48.56788	48.16407	50.10417	49.16307
51.70000	51.68100	51.23035	50.40152	50.12334	48.56701	48.23585	50.12179	49.20255
51.80000	51.78100	51.22891	50.48825	50.14112	48.56604	48.32814	50.13904	49.24784
51.90000	51.88100	51.21974	50.56456	50.15923	48.56519	48.42812	50.15649	49.29972
46.00000	-50.19000	51.13535	50.25566	-48.4232u	48.64813	-46.51272	-48.42114	48.64953
46.00000	-50.19000	-51.74713	12.00000	47.81060	-46.14452	12.00000	47.81054	-46.17143

TABLE X

Force Data for the Flat Double Delta Wing

Run 17 No trip (0)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.36000	-51.41991	51.14791	-47.40361	-46.20910	-46.29856	-47.40373	-46.18372
46.00000	-50.36000	51.44971	-50.33781	-48.71014	48.65626	47.11942	-48.70600	48.66071
-51.20000	-51.23600	51.33371	-50.12715	-49.46992	48.64508	47.29856	-49.46686	48.83804
-51.20000	-51.23600	51.31480	-50.15063	-49.47600	48.65240	47.35827	-49.47291	48.84785
-51.10000	-51.13600	51.35722	-50.22260	-49.26856	48.66217	47.29856	-49.26691	48.72572
46.00000	-50.36000	51.34232	-50.50478	-48.71288	48.66005	47.17914	-48.70872	48.66452
51.10000	50.64000	51.38607	-50.20085	49.11861	48.64999	-47.11942	49.11788	48.66320
51.20000	51.16400	51.33467	-50.22264	49.32155	48.63293	-47.35827	49.31960	48.72470
51.30000	51.26400	51.22078	-50.17130	49.55743	48.62503	-47.47770	49.55396	48.88111
51.40000	51.36400	51.28796	-50.11241	49.74339	48.62619	-47.41799	49.73792	49.10969
51.50000	51.46400	51.27232	-49.68732	49.95536	48.63237	-47.32842	49.94712	49.14031
46.00000	-50.36000	-51.41991	51.14791	47.40361	46.20910	46.29856	47.40373	46.18372

Run 18 No trip (0)

46.00000	-50.46000	-52.12841	-50.49953	48.11955	-46.32387	-46.29856	48.11952	-46.41985
-51.20000	-51.24600	51.27916	-50.23181	-49.48972	48.63084	47.56726	-49.48656	48.84045
-51.10000	-51.14600	-51.57436	-49.35147	-50.13594	48.58608	47.23885	-50.13575	48.93230
46.00000	-50.46000	51.30221	-50.14736	-48.81344	48.64247	46.59712	-48.80825	48.64898
51.10000	50.54000	51.51266	-50.34861	49.10247	48.63592	-47.17914	49.10187	48.64555
-51.20000	-51.24600	51.26536	-50.20598	-49.49312	48.64969	47.50755	-49.48988	48.86074
-51.10000	-51.14600	51.26274	-50.16583	-49.28837	48.65933	47.23885	-49.28660	48.73260
46.00000	-50.46000	51.11299	-49.64063	-48.93519	48.65711	46.29856	-48.92988	48.66459
51.10000	50.54000	51.63916	-50.17871	48.99928	48.65861	-46.89568	48.99303	48.66800
51.20000	51.15400	51.41331	-50.20006	49.29817	48.65274	-47.29856	49.29631	48.73263
51.30000	51.25400	51.35047	-50.16524	49.50562	48.65111	-47.41799	49.50224	48.87453
51.40000	51.35400	51.32501	-49.66672	49.71620	48.63821	-47.23885	49.71089	49.10792
51.50000	51.45400	51.31497	49.25959	49.91983	48.62880	47.11942	49.91197	49.13549
51.50000	51.45400	51.31749	49.32488	49.91870	48.62114	47.14928	49.91091	49.13464
51.60000	51.55400	51.29803	50.10589	50.11276	48.62337	47.59712	50.11163	49.17090
51.70000	51.65400	51.28665	50.15304	50.13263	48.60992	48.10151	50.13108	49.21166
51.80000	51.75400	51.28843	50.20483	50.15157	48.61124	48.15525	50.14945	49.25947
51.90000	51.85400	51.27871	50.23729	50.17109	48.62423	48.20302	50.16827	49.31579
46.00000	-50.46000	51.32844	-51.12956	-48.78666	48.67301	47.50755	-48.78124	48.67931
46.00000	-50.46000	-52.12847	-50.49953	-48.11952	-46.43647	46.29856	-48.11955	-46.34049

Run 19 With trip (4)

46.00000	-50.33000	-51.64932	51.18335	-47.32532	-46.77568	-46.29856	-47.32576	-46.75693
-51.20000	-51.23300	51.33614	-50.33644	-49.46180	48.73100	47.77626	-49.45845	48.91815
-51.10000	-51.13300	51.36591	-50.26904	-49.26669	48.74779	47.35827	-49.26488	48.8094u
46.00000	-50.33000	51.56125	-50.44875	-48.66887	48.75340	47.14928	-48.66452	48.75724
51.10000	50.67000	51.31978	12.00000	49.11806	48.74691	12.00000	49.11718	48.76066
51.20000	51.16700	51.29360	-50.13043	49.32013	48.73361	-47.20899	49.31786	48.82659
51.30000	51.26700	51.29570	-50.13814	49.51838	48.72014	-47.35827	49.51447	48.96084
51.40000	51.36700	51.27357	-49.65237	49.73192	48.69978	-47.23885	49.72595	49.11668
51.50000	51.46700	51.27208	-48.63833	49.93513	48.68274	-46.29856	49.92647	49.14418
51.60000	51.56700	51.26422	49.98841	50.11475	48.69274	47.56726	50.11351	49.18231
51.70000	51.66700	51.26165	50.15528	50.13456	48.66786	48.10450	50.13288	49.22262
51.80000	51.76700	51.26063	50.19778	50.15395	48.68079	48.15227	50.15166	49.27293
51.90000	51.86700	51.25466	50.23705	50.17378	48.69013	48.20601	50.17075	49.33017
46.00000	-50.33000	51.88119	-51.17792	-48.57421	48.77666	47.50755	-48.56973	48.77995
46.00000	-50.33000	-51.64369	51.18335	47.32621	-47.11252	46.29856	47.32556	-47.11439

TABLE X

Force Data for the Flat Double Delta Wing (concl'd)

Run 21 With trip (4)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.42000	50.95157	12.00000	-47.29114	47.11268	12.00000	-47.29031	47.11481
46.00000	-50.42000	51.30815	-50.36145	-48.82961	48.76405	47.14928	-48.82399	48.77011
-51.60000	-51.64200	51.28387	49.65038	-50.12857	48.71501	-47.41799	-50.12696	49.21481
-51.50000	-51.54200	51.28645	12.00000	-50.10899	48.70902	12.00000	-50.10783	49.17353
-51.40000	-51.44200	51.28418	-49.60191	-49.89319	48.71829	47.26870	-49.88500	49.14045
-51.30000	-51.34200	51.28276	-50.12082	-49.69226	48.72775	47.41799	-49.68669	49.11394
-51.20000	-51.24200	51.29330	-50.14743	-49.48638	48.74125	47.35827	-49.48282	48.94597
-51.10000	-51.14200	51.29480	-50.16848	-49.28389	48.75079	47.23885	-49.28194	48.82091
46.00000	-50.42000	51.24859	-50.21504	-48.83663	48.76402	46.89568	-48.83100	48.77013
51.10000	50.58000	51.44102	-49.55431	49.10737	48.75781	-46.29856	49.10660	48.76864
51.20000	51.15800	51.35266	-49.95629	49.31186	48.74843	-47.14928	49.30968	48.83413
51.30000	51.25800	51.33304	-49.81388	49.51323	48.73130	-47.20899	49.50942	48.96156
51.40000	51.35800	51.30975	-49.16466	49.72494	48.71846	-46.59712	49.71904	49.11697
51.50000	51.45800	51.30491	49.25832	49.92432	48.70124	47.11942	49.91577	49.14371
51.60000	51.55800	51.29157	49.95145	50.11294	48.69949	47.53741	50.11172	49.17942
51.70000	51.65800	51.29721	50.16268	50.13211	48.69712	48.10748	50.13044	49.22063
51.80000	51.75800	51.27938	50.21960	50.15224	48.69139	48.16719	50.15000	49.26935
51.90000	51.85800	51.27226	50.28147	50.17181	48.68160	48.24183	50.16887	49.32371
46.00000	-50.42000	51.28067	-50.35657	-48.84092	48.76400	47.14928	-48.83530	48.77014

Run 22 With trip (4)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.45000	51.28677	-50.86270	-48.83417	48.76023	47.35827	-48.82818	48.76676
-51.60000	-51.64500	51.26730	49.34101	-50.13136	48.74220	-47.22392	-50.12970	49.22132
-51.40000	-51.44500	51.26754	-49.87519	-49.92144	48.74357	47.40306	-49.91289	49.14562
-51.20000	-51.24500	51.28852	-50.25351	-49.49499	48.74655	47.62698	-49.49135	48.95746
46.00000	-50.45000	51.21635	-50.90787	-48.89151	48.75996	47.40306	-48.88551	48.76694
51.20000	51.15500	51.38665	49.86425	49.31056	48.74457	47.13435	49.30844	48.82829
51.40000	51.35500	51.30449	49.36327	49.73935	48.73625	47.13435	49.73337	49.11926
51.60000	51.55500	51.29086	50.14077	50.11450	48.73824	47.80611	50.11325	49.18421
51.80000	51.75500	51.29473	50.24717	50.15217	48.72177	48.18809	50.14990	49.27148
51.10000	50.55000	51.43723	50.32353	49.11038	48.76935	47.17914	49.10963	48.77991
-51.10000	-51.14500	51.31492	-50.34096	-49.28933	48.76764	47.49262	-49.28730	48.84060
-51.30000	-51.34500	51.28013	-50.17728	-49.70769	48.74793	47.62698	-49.70191	49.11725
46.00000	-50.45000	51.21638	-50.80699	-48.89156	48.77136	47.35827	-48.88548	48.77834
46.00000	-50.45000	50.90111	12.00000	47.43563	46.59078	12.00000	47.43608	46.55654

Run 23 With trip (4)

α	α_c	y_{cp}	x_{cp}	C_z	C_x	C_m	C_L	C_D
46.00000	-50.36000	52.18138	12.00000	-46.99491	-44.46858	12.00000	-46.99492	44.15679
46.00000	-50.36000	51.41810	-50.41115	-48.72973	48.75692	47.14928	-48.72495	48.76149
-51.60000	-51.63600	51.28490	49.69958	-50.12807	48.71525	-47.44784	-50.12649	49.21295
-51.50000	-51.53600	51.29188	48.55175	-50.10826	48.71317	-46.29856	-50.10712	49.17213
-51.40000	-51.43600	51.29597	-49.54082	-49.88364	48.72254	47.23885	-49.87559	49.13922
-51.30000	-51.33600	51.31102	-50.12361	-49.67663	48.73989	47.41799	-49.67113	49.11352
-51.20000	-51.23600	51.33296	-50.16613	-49.46762	48.74213	47.38813	-49.46417	48.93406
-51.10000	-51.13600	51.33209	-50.21919	-49.27278	48.75511	47.29856	-49.27091	48.81964
46.00000	-50.36000	51.41571	-50.50422	-48.71412	48.75699	47.17914	-48.70935	48.76146
51.20000	51.16400	51.31820	-49.37116	49.32141	48.75648	-46.59712	49.31911	48.84816
51.40000	51.36400	51.29472	12.00000	49.73293	48.72644	12.00000	49.72684	49.11903
51.60000	51.56400	51.28304	49.99316	50.11420	48.70389	47.56726	50.11296	49.18228
51.80000	51.76400	51.26993	50.22158	50.15358	48.69582	48.17018	50.15129	49.27313
46.00000	-50.36000	51.38555	-50.40485	-48.74116	48.78348	47.14928	-48.73622	48.78812
46.00000	-50.36000	52.18138	12.00000	46.99491	44.46858	12.00000	46.99492	-44.15679

TABLE XI

Force Data for the Warped Arrow Wing

Run 4 With trip (3)

α	α_{cp}	x_{cp}	C_z	C_x	C_m	C_ℓ	C_L	C_D	L/D
46.00000	51.89351	50.81443	49.78832	49.12394	48.30948	50.28715	49.78832	49.12394	51.6[illegible]
-52.10000	-52.10862	49.50592	-50.10616	48.15983	47.25577	-50.39415	-50.10427	49.20008	-51.52113
-51.90000	-52.10952	50.19835	-49.86606	48.29521	47.81847	-50.32231	-49.85078	49.16464	-51.51376
-51.80000	-52.11588	50.39738	-49.67461	48.42303	48.12789	-50.251[illegible]	-49.66206	49.13576	-51.48736
-51.70000	-52.13659	50.73622	-49.47827	48.55839	48.16661	-50.18115	-49.46790	49.11371	-51.41149
-51.60000	-52.19354	51.14091	-49.28928	48.68670	48.19950	-50.11036	-49.28052	48.98532	-51.26470
-51.50000	-52.42754	51.35570	-49.10087	48.80436	48.22252	-49.39261	-48.96464	48.89183	-51.10816
-51.40000	52.45821	51.41922	48.76878	48.91059	48.21787	49.32658	48.83041	48.85454	50.97176
-51.30000	52.18263	51.19154	49.26134	49.10169	48.25577	50.10021	49.26630	48.87676	51.30304
-51.20000	52.12108	51.12571	49.43512	49.10936	48.26856	50.16469	49.43667	48.94105	51.46615
-51.10000	51.98407	50.95779	49.61688	49.11813	48.28647	50.22688	49.61885	49.10734	51.57652
46.00000	51.89902	50.82338	49.78607	49.12436	48.31204	50.28814	49.78607	49.12436	51.63209
51.10000	51.88532	50.77079	49.95263	49.13139	48.35297	50.34921	49.95020	49.14799	51.64205
51.20000	51.90540	50.76158	50.11269	49.13944	48.41179	50.40280	50.11213	49.17868	51.62757
51.30000	51.95242	50.76387	50.12854	49.14700	48.47062	50.45811	50.12760	49.21408	51.59604
51.40000	52.10128	50.78706	50.14385	49.15443	48.54224	50.51188	50.14242	49.25440	51.55985
51.50000	52.10799	50.81527	50.15928	49.16176	48.62153	50.56113	50.15726	49.29996	51.52426
46.00000	51.89950	50.83013	49.78607	49.12443	48.31460	50.28814	49.78607	49.12443	51.63174
46.00000	51.50000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000

Run 5 No trip (0)

51.50000	51.30100	51.51450	52.63000	52.21000					
46.00000	51.50000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000
46.00000	51.87545	50.81039	49.77299	49.11904	48.30181	50.28887	49.77299	49.11904	51.64958
-52.10000	-52.10361	49.54623	-50.10816	47.68235	47.28135	-50.39281	-50.10640	49.19454	-51.54693
-51.90000	-52.10596	50.19405	-49.88541	48.24675	47.81847	-50.32145	-49.87065	49.16288	-51.55[illegible]
-51.80000	-52.11142	50.37080	-49.69427	48.38107	48.12277	-50.25165	-49.68221	49.15[illegible]	-51.5[illegible]
-51.70000	-52.13048	50.68516	-49.49113	48.52040	48.16114	-50.17924	[illegible]	-49.11151	-51.[illegible]
-51.60000	-52.17890	51.13049	-49.30613	48.64455	48.19439	-50.10932	-49.29771	48.96100	-51.[illegible]
-51.50000	-52.38108	51.32669	-49.11706	48.76334	48.21741	-49.38528	-49.10996	48.86246	-51.12750
-51.40000	52.49961	51.46138	48.63014	48.86604	48.23531	49.31021	48.68902	48.81998	50.84029
-51.30000	52.18937	51.20060	49.24092	48.97027	48.24810	49.97539	49.24567	48.84286	51.29[illegible]
-51.20000	52.11809	51.12254	49.42564	49.10462	48.25577	50.16511	49.42904	48.897[illegible]	51.47[illegible]
-51.10000	51.96117	50.90185	49.60881	49.11406	48.26600	50.22799	49.61071	49.10[illegible]	51.59[illegible]
46.00000	51.87795	50.81036	49.77296	49.11958	48.30181	50.288[illegible]	49.772[illegible]	49.11958	51.6[illegible]
51.10000	51.86814	50.76994	49.94024	49.12681	48.[illegible]785	50.34827	49.93789	49.14320	51.65[illegible]95
51.20000	51.89306	50.76467	50.11087	49.13476	48.40668	50.39914	50.11[illegible]	49.17[illegible]	51.6[illegible]
51.30000	51.94374	50.77413	50.12686	49.14310	48.47262	50.45513	50.12594	49.20933	51.60162
51.40000	52.10012	50.78857	50.14225	49.14981	48.53712	50.50723	50.14086	49.24867	51.56646
51.50000	52.10690	50.79478	50.15[illegible]	49.15745	48.60107	50.56019	50.15603	49.29458	51.52977
46.00000	51.87449	50.80[illegible]01	49.77914	49.11985	48.30181	50.28875	49.77914	49.11985	51.65[illegible]11
46.00000	51.50000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000

TABLE XII

Force Data for the Warped Double Delta Wing

Run 8 With trip (3)

α	α_{cp}	x_{cp}	C_z	C_x	C_m	C_l	C_L	C_D	L/D
46.00000	51.92071	49.88911	49.79371	49.12865	47.35745	50.22669	49.79370	49.12865	51.61695
-52.10000	-51.99604	-50.20880	-50.12554	-46.85726	-48.13107	-50.36485	-50.12365	49.21716	-51.56940
-51.90000	-51.97035	-50.13592	-50.10519	48.12923	-47.71490	-50.30725	-50.10369	49.17731	-51.58479
-51.80000	-51.97761	-49.28022	-49.85000	48.26363	-47.11915	-50.24687	-49.83806	49.14440	-51.58037
-51.70000	-52.10599	50.15774	-49.64079	48.40314	47.50639	-50.18896	-49.63110	49.11811	-51.53435
-51.60000	-52.13229	50.37252	-49.42837	48.54339	47.80426	-50.12992	-49.42034	48.98817	-51.42537
-51.50000	-52.22213	50.67377	-49.21960	48.68033	47.77448	-49.69641	-49.21283	48.86913	-51.24488
-51.40000	-52.86186	51.19523	-48.11202	48.81626	47.80426	-49.10341	-47.54807	48.82209	-49.66668
-51.30000	52.25262	50.72327	49.17412	48.93606	47.71490	49.53423	49.17878	48.84365	51.21191
-51.20000	52.13647	50.25789	49.37816	49.10592	47.50639	50.11200	49.38162	48.92655	51.41188
-51.10000	52.10394	50.13975	49.58505	49.11790	47.41703	50.17073	49.58702	49.10767	51.54521
46.00000	51.92736	49.96948	49.78841	49.12873	47.38724	50.22736	49.78841	49.12873	51.61245
51.10000	51.91005	49.90165	49.98121	49.13965	47.44681	50.28531	49.97862	49.15675	51.62431
51.20000	51.92292	50.10976	50.11846	49.15027	47.65533	50.33859	50.11787	49.19151	51.61545
51.30000	51.96792	50.13386	50.13703	49.16046	47.92341	50.39233	50.13600	49.23195	51.58632
51.40000	52.10298	50.17109	50.15575	49.17189	48.13404	50.44328	50.15417	49.28011	51.55039
51.50000	52.11004	50.21759	50.17427	49.18326	48.19064	50.49270	50.17201	49.33445	51.51431
46.00000	51.91483	50.10933	49.80701	49.12996	47.44681	50.22551	49.80701	49.12996	51.62098
46.00000	51.40000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000	12.00000

Run 9 No trip (0)

46.00000	51.89720	50.83668	49.77996	49.12314	48.31460	50.28826	49.77996	49.12314	51.63339
-52.10000	-52.10813	49.60237	-50.10699	48.15183	47.30693	-50.39305	-50.10510	49.20074	-51.52357
-51.90000	-52.10881	50.20874	-49.87442	48.28721	47.86963	-50.32120	-49.85917	49.16516	-51.52022
-51.80000	-52.11478	50.40826	-49.68288	48.41503	48.13300	-50.25022	-49.67046	49.13613	-51.49250
-51.70000	-52.13478	50.74745	-49.48553	48.55135	48.17393	-50.18054	-49.47519	49.11390	-51.41722
-51.60000	-52.18909	51.14124	-49.29655	48.67966	48.20462	-50.10975	-49.28782	48.98591	-51.29193
-51.50000	-52.40359	51.34738	-49.11223	48.79636	48.22764	-49.38154	-49.10486	48.89114	-51.11767
-51.40000	52.48792	51.45036	48.68516	48.90239	48.24298	49.53745	48.74644	48.85240	50.37569
-51.30000	52.18744	51.20116	49.25297	49.10089	48.26339	50.10132	49.25791	48.87515	51.29470
-51.20000	52.12249	51.13019	49.42785	49.10865	48.27368	50.16530	49.43138	48.93655	51.46061
-51.10000	51.99154	50.98628	49.60961	49.11756	48.29158	50.22749	49.61157	49.10690	51.57203
46.00000	51.90276	50.84579	49.77771	49.12356	48.31716	50.28924	49.77771	49.12356	51.62941
51.10000	51.88742	50.78834	49.94428	49.13059	48.35303	50.35031	49.94185	49.14705	51.64050
51.20000	51.90678	50.77755	50.11174	49.13854	48.41691	50.40440	50.11119	49.17746	51.62659
51.30000	51.95324	50.77739	50.12760	49.14611	48.47574	50.45971	50.12666	49.21269	51.59552
51.40000	52.10132	50.79973	50.14291	49.15354	48.54735	50.51348	50.14149	49.25284	51.55959
51.50000	52.10801	50.82688	50.15833	49.16086	48.62664	50.56273	50.15633	49.29824	51.52416
46.00000	51.90327	50.85261	49.77771	49.12363	48.31972	50.28924	49.77771	49.12363	51.62906
46.00000	51.54658	51.12789	-47.83617	-46.80007	46.51155	48.11076	-47.83617	-46.80007	52.10451

TABLE XIII

Flat Arrow Wing Pressure Data

(a) Bad Pressure Taps

y/b \ x/c	.010	.025	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	
.10	--	--	--	--	--	--	--	--	--	--	--	--	TOP
.25	--	--	--	--	--	--	--	--	--	--	--	--	
.40	--	--	--	--	--	--	--	--	--	--	--	--	
.55	--	--	--	--	--	--	--	--	--	--	--	xxxx	
.70		--	--	--	--	--	--	--	--	--	--		
.85				--	--	--	--	--	--	--			
.10	--	--	--	--	--	--	--	--	--	--	xxxx	--	BTM
.25	--	--	--	--	xxxx	--	xxxx	--	--	--	--	--	
.40	--	xxxx	--	--	--	--	--	--	--	--	--	--	
.55	--	--	--	--	--	--	--	--	--	--	--	--	
.70		--	--	--	--	xxxx	--	--	--	--	--		
.85				--	--	--	--	--	--	--			
.10	--	--	--	--	--	--	--	--	--	--	xxxx	--	DIFF
.25	--	--	--	--	xxxx	--	xxxx	--	--	--	--	--	
.40	--	xxxx	--	--	--	--	--	--	--	--	--	--	
.55	--	--	--	--	--	--	--	--	--	--	--	xxxx	
.70		--	--	--	--	xxxx	--	--	--	--	--		
.85				--	--	--	--	--	--	--			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(b) Run 5 – No boundary layer trip

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0575	.0476	.0404	.0371	.0299	.0101	.0226	.0187	.0226	.0154	.0095	.0049	
.2500	.0413	.0381	.0308	.0262	.0183	.0151	.0078	-.0006	-.0052	-.0052	-.0072	-.0091	T
.4000	.0601	.0555	.0535	.0397	.0345	.0226	.0180	.0118	.0006	.0006	-.0006	.0026	O
.5500	.0486	.0459	.0407	.0367	.0229	.0065	.0006	-.0059	-.0118	-.0157	-.0164	-.0334	P
.7000		.0591	.0696	.0558	.0315	.0223	.0137	.0926	-.0059	-.0098	-.0052		
.8500				.0367	.0203	.0091	-.0026	-.0118	-.0229	-.0275			
.1000	.0062	-.0023	-.0016	-.0003	-.0023	.0062	-.0055	-.0101	-.0128	-.0154	-.0312	-.0207	
.2500	-.0289	-.0289	-.0249	-.0243	-.0183	-.0229	-.0295	-.0328	-.0321	-.0341	-.0354	-.0341	B
.4000	-.0358	-.0207	-.0272	-.0200	-.0200	-.0233	-.0253	-.0295	-.0315	-.0295	-.0295	-.0295	T
.5500	-.0624	-.0663	-.0558	-.0571	-.0473	-.0479	-.0433	-.0512	-.0551	-.0604	-.0525	-.0446	M
.7000		-.0670	-.0637	-.0617	-.0624	-.0630	-.0624	-.0604	-.0597	-.0597	-.0558		
.8500				-.0978	-.0971	-.0971	-.0978	-.0991	-.1004	-.1017			
.1000	-.0512	-.0499	-.0420	-.0374	-.0322	-.0039	-.0282	-.0289	-.0354	-.0308	-.0407	-.0256	D
.2500	-.0703	-.0670	-.0538	-.0505	-.0367	-.0381	-.0374	-.0321	-.0269	-.0289	-.0282	-.0249	I
.4000	-.0959	-.0762	-.0808	-.0598	-.0545	-.0460	-.0433	-.0413	-.0321	-.0302	-.0289	-.0321	F
.5500	-.1110	-.1123	-.0965	-.0939	-.0703	-.0545	-.0440	-.0453	-.0433	-.0446	-.0361	-.0111	F
.7000		-.1261	-.1333	-.1176	-.0939	-.0854	-.0762	-.0630	-.0538	-.0499	-.0505		
.8500				-.1346	-.1175	-.1063	-.0952	-.0873	-.0774	-.0742			

$\alpha = -1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0364	.0285	.0193	.0174	.0108	-.0009	.0042	.0003	.0062	-.0022	-.0082	-.0134	
.2500	.0328	.0282	.0210	.0164	.0091	.0045	.0006	-.0065	-.0065	-.0105	-.0131	-.0151	T
.4000	.0397	.0351	.0312	.0193	.0121	.0022	-.0022	-.0085	-.0183	-.0177	-.0183	-.0157	O
.5500	.0387	.0282	.0282	.0223	.0183	-.0032	-.0078	-.0147	-.0200	-.0226	-.0232	-.0193	P
.7000		.0413	.0433	.0223	.0072	-.0019	-.0085	-.0190	-.0275	-.0302	-.0242		
.8500				.0272	.0121	.0009	-.0101	-.0206	-.0285	-.0344			
.1000	.0082	-.0016	-.0049	-.0055	-.0009	-.0022	-.0121	-.0154	-.0193	-.0200	-.0154	-.0272	
.2500	.0032	-.0065	-.0085	-.0137	-.0098	-.0144	-.0216	-.0262	-.0256	-.0269	-.0275	-.0282	B
.4000	-.0141	-.0259	-.0160	-.0167	-.0193	-.0246	-.0279	-.0334	-.0367	-.0341	-.0348	-.0315	T
.5500	-.0229	-.0335	-.0295	-.0256	-.0282	-.0341	-.0348	-.0390	-.0449	-.0436	-.0429	-.0357	M
.7000		-.0492	-.0472	-.0426	-.0420	-.0453	-.0485	-.0551	-.0564	-.0597	-.0558		
.8500				-.0633	-.0613	-.0613	-.0653	-.0672	-.0685	-.0712			
.1000	-.0282	-.0302	-.0243	-.0229	-.0118	-.0013	-.0164	-.0157	-.0256	-.0177	-.0072	-.0137	D
.2500	-.0295	-.0348	-.0295	-.0302	-.0190	-.0190	-.0223	-.0197	-.0190	-.0164	-.0144	-.0131	I
.4000	-.0518	-.0611	-.0473	-.0361	-.0315	-.0269	-.0256	-.0249	-.0183	-.0164	-.0164	-.0157	F
.5500	-.0617	-.0617	-.0578	-.0479	-.0466	-.0308	-.0269	-.0242	-.0249	-.0210	-.0196	-.0164	F
.7000		-.0906	-.0906	-.0650	-.0492	-.0433	-.0400	-.0361	-.0288	-.0295	-.0315		
.8500				-.0905	-.0735	-.0623	-.0551	-.0465	-.0400	-.0367			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(c) Run 6 – No boundary layer trip (repeat of Run 5)

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0571	.0479	.0413	.0367	.0295	.0085	.0210	.0177	.0216	.0150	.0085	.0039	
.2500	.0518	.0485	.0413	.0367	.0288	.0255	.0229	.0105	.0091	.0065	.0039	.0019	T
.4000	.0590	.0538	.0518	.0387	.0334	.0216	.0177	.0111	.0000	.0000	-.0013	.0019	O
.5500	.0597	.0571	.0518	.0472	.0334	.0144	.0111	.0045	-.0013	-.0052	-.0059	.4440	P
.7000		.0590	.0682	.0485	.0308	.0216	.0131	.0019	-.0065	-.0111	-.0059		
.8500				.0472	.0308	.0196	.0078	-.0026	-.0131	-.0170			
.1000	.0078	-.0019	-.0013	-.0006	-.0026	.0032	-.0065	-.0105	-.0137	-.0157	-.0315	-.0216	
.2500	-.0183	-.0183	-.0150	-.0131	-.0065	-.0118	-.0236	-.0216	-.0216	-.0229	-.0242	-.0229	B
.4000	-.0367	-.0210	-.0282	-.0216	-.0203	-.0242	-.0262	-.0295	-.0321	-.0301	-.0301	-.0268	T
.5500	-.0511	-.0544	-.0498	-.0459	-.0360	-.0360	-.0354	-.0393	-.0446	-.0426	-.0419	-.0341	M
.7000		-.0662	-.0636	-.0610	-.0616	-.0623	-.0629	-.0610	-.0596	-.0596	-.0557		
.8500				-.0879	-.0865	-.0865	-.0872	-.0885	-.0905	-.0911			
.1000	-.0492	-.0498	-.0426	-.0374	-.0321	-.0052	-.0275	-.0282	-.0354	-.0308	-.0400	-.0255	D
.2500	-.0702	-.0669	-.0564	-.0498	-.0354	-.0374	-.0465	-.0321	-.0308	-.0295	-.0282	-.0249	I
.4000	-.0958	-.0748	-.0800	-.0603	-.0538	-.0459	-.0439	-.0406	-.0321	-.0301	-.0288	-.0288	F
.5500	-.1109	-.1115	-.1017	-.0931	-.0695	-.0505	-.0465	-.0439	-.0432	-.0373	-.0360	-.4782	F
.7000		-.1252	-.1318	-.1095	-.0924	-.0839	-.0760	-.0629	-.0531	-.0485	-.0498		
.8500				-.1351	-.1174	-.1062	-.0951	-.0859	-.0774	-.0741			

$\alpha = -1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0574	.0397	.0298	.0278	.0200	.0022	.0141	.0108	.0147	.0075	.0016	-.0029	
.2500	.0423	.0377	.0311	.0252	.0193	.0160	.0167	.0029	.0016	-.0009	-.0029	-.0055	T
.4000	.0488	.0443	.0410	.0292	.0219	.0121	.0082	.0026	-.0078	-.0072	-.0085	-.0045	O
.5500	.0488	.0449	.0390	.0324	.0219	.0068	.0016	-.0052	-.0104	-.0137	-.0150	.0997	P
.7000		.0531	.0537	.0321	.0183	.0091	.0026	-.0085	-.0177	-.0209	-.0150		
.8500				.0334	.0150	.0052	-.0045	-.0163	-.0242	-.0282			
.1000	.0219	.0108	.0068	.0049	.0022	-.0049	-.0009	-.0055	-.0088	-.0101	-.0055	-.0173	
.2500	.0042	.0016	-.0003	-.0049	.0009	-.0042	-.0167	-.0160	-.0160	-.0173	-.0187	-.0180	B
.4000	-.0042	-.0226	-.0055	-.0062	-.0088	-.0147	-.0173	-.0223	-.0255	-.0236	-.0242	-.0209	T
.5500	-.0141	-.0239	-.0206	-.0167	-.0187	-.0246	-.0252	-.0308	-.0367	-.0354	-.0347	-.0262	M
.7000		-.0380	-.0354	-.0308	-.0308	-.0341	-.0373	-.0432	-.0478	-.0518	-.0485		
.8500				-.0564	-.0544	-.0557	-.0603	-.0616	-.0636	-.0655			
.1000	-.0354	-.0288	-.0229	-.0229	-.0177	-.0072	-.0150	-.0164	-.0236	-.0177	-.0072	-.0144	D
.2500	-.0380	-.0360	-.0315	-.0301	-.0183	-.0203	-.0334	-.0190	-.0177	-.0164	-.0157	-.0124	I
.4000	-.0531	-.0669	-.0465	-.0354	-.0308	-.0269	-.0255	-.0249	-.0177	-.0163	-.0157	-.0163	F
.5500	-.0630	-.0689	-.0597	-.0492	-.0406	-.0315	-.0269	-.0255	-.0262	-.0216	-.0196	-.1259	F
.7000		-.0911	-.0892	-.0629	-.0491	-.0432	-.0400	-.0347	-.0301	-.0308	-.0334		
.8500				-.0898	-.0695	-.0610	-.0557	-.0452	-.0393	-.0373			

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0390	.0285	.0206	.0187	.0134	-.0022	.0075	.0042	.0075	.0003	-.0049	-.0088	
.2500	.0288	.0255	.0203	.0150	.0098	.0078	.0098	-.0032	-.0032	-.0065	-.0091	-.0111	T
.4000	.0344	.0298	.0272	.0187	.0121	.0022	-.0009	-.0059	-.0150	-.0144	-.0150	-.0072	O
.5500	.0301	.0269	.0223	.0177	.0098	-.0026	-.0085	-.0157	-.0183	-.0216	-.0229	.0209	P
.7000		.0327	.0308	.0131	.0019	-.0045	-.0118	-.0216	-.0275	-.0301	-.0262		
.8500				.0104	-.0045	-.0137	-.0216	-.0301	-.0380	-.0419			
.1000	.0351	.0213	.0154	.0108	.0062	-.0029	.0029	-.0003	-.0042	-.0042	.0167	-.0127	
.2500	.0216	.0170	.0118	.0052	.0091	.0032	-.0105	-.0105	-.0105	-.0111	-.0131	-.0131	B
.4000	.0213	-.0108	.0127	.0088	.0022	-.0049	-.0088	-.0157	-.0190	-.0177	-.0190	-.0157	T
.5500	.0223	.0065	.0039	.0032	-.0032	-.0124	-.0150	-.0209	-.0282	-.0275	-.0268	-.0196	M
.7000		.0072	.0000	-.0032	-.0104	-.0170	-.0216	-.0308	-.0354	-.0400	-.0341		
.8500				-.0124	-.0203	-.0295	-.0347	-.0413	-.0459	-.0511			
.1000	-.0039	-.0072	-.0052	-.0078	-.0072	-.0006	-.0045	-.0045	-.0118	-.0045	.0216	-.0039	D
.2500	-.0072	-.0085	-.0085	-.0098	-.0006	-.0045	-.0203	-.0072	-.0072	-.0045	-.0039	-.0019	I
.4000	-.0131	-.0406	-.0144	-.0098	-.0098	-.0072	-.0078	-.0098	-.0039	-.0032	-.0039	-.0085	F
.5500	-.0078	-.0203	-.0183	-.0144	-.0131	-.0098	-.0065	-.0052	-.0098	-.0059	-.0039	-.0406	F
.7000		-.0255	-.0308	-.0163	-.0124	-.0124	-.0098	-.0091	-.0078	-.0098	-.0078		
.8500				-.0229	-.0157	-.0157	-.0131	-.0111	-.0078	-.0091			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(c) Run 6 – No boundary layer trip (repeat of Run 5) (cont'd)

$\alpha = 1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0259	.0180	.0121	.0423	.0062	-.0075	.0022	-.0016	.0022	-.0062	-.0108	-.0134	
.2500	.0137	.0118	.0078	.0052	.0026	.0000	.0039	-.0098	-.0085	-.0124	-.0157	-.0164	T
.4000	.0121	.0101	.0095	.0036	.0016	-.0068	-.0095	-.0137	-.0223	-.0209	-.0209	-.0163	O
.5500	.0045	.0006	-.0006	-.0006	-.0052	-.0137	-.0190	-.0242	-.0275	-.0295	-.0301	-.0045	P
.7000		-.0013	-.0019	-.0137	-.0157	-.0203	-.0262	-.0341	-.0287	-.0413	-.0367		
.8500				-.0255	-.0314	-.0373	-.0419	-.0491	-.0537	-.0564			
.1000	.0495	.0324	.0246	.0200	.0127	.0036	.0036	.0055	.0016	.0022	.0344	-.0082	
.2500	.0380	.0308	.0236	.0157	.0170	.0111	-.0032	-.0039	-.0045	-.0045	-.0072	-.0085	B
.4000	.0403	-.0055	.0292	.0219	.0141	.0042	-.0003	-.0078	-.0118	-.0104	-.0124	-.0098	T
.5500	.0459	.0295	.0236	.0196	.0105	-.0019	-.0052	-.0111	-.0190	-.0190	-.0190	-.0118	M
.7000		.0387	.0262	.0190	.0085	-.0006	-.0065	-.0190	-.0249	-.0295	-.0236		
.8500				.0150	.0039	-.0052	-.0157	-.0242	-.0295	-.0354			
.1000	.0236	.0144	.0124	-.0223	.0065	.0111	.0013	.0072	-.0006	.0085	.0452	.0052	D
.2500	.0242	.0190	.0157	.0105	.0144	.0111	-.0072	.0059	.0039	.0078	.0085	.0078	I
.4000	.0282	-.0157	.0196	.0183	.0124	.0111	.0091	.0059	.0104	.0104	.0085	.0065	F
.5500	.0413	.0288	.0242	.0203	.0157	.0118	.0137	.0131	.0085	.0104	.0111	-.0072	F
.7000		.0400	.0282	.0327	.0242	.0196	.0196	.0150	.0137	.0118	.0131		
.8500				.0406	.0354	.0321	.0262	.0249	.0242	.0209			

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0124	.0065	.0019	.0013	.0006	-.0118	.0006	-.0072	-.0032	-.0118	-.0157	-.0177	
.2500	-.0042	-.0062	-.0068	-.0068	-.0055	-.0075	-.0016	-.0160	-.0147	-.0187	-.0206	-.0206	T
.4000	-.0157	-.0137	-.0111	-.0118	-.0105	-.0150	-.0183	-.0213	-.0291	-.0272	-.0272	-.0213	O
.5500	-.0311	-.0292	-.0265	-.0226	-.0226	-.0272	-.0292	-.0324	-.0364	-.0370	-.0370	-.0154	P
.7000		-.0449	-.0423	-.0436	-.0409	-.0409	-.0429	-.0482	-.0462	-.0475	-.0455		
.8500				-.0711	-.0672	-.0678	-.0685	-.0705	-.0724	-.0737			
.1000	.0597	.0426	.0354	.0406	.0190	.0144	.0144	.0118	.0078	.0091	.0472	-.0019	
.2500	.0508	.0423	.0338	.0252	.0252	.0193	.0029	.0029	.0003	.0016	-.0009	-.0022	B
.4000	.0531	.0479	.0426	.0413	.0242	.0144	.0085	-.0003	-.0042	-.0036	-.0055	-.0036	T
.5500	.0574	.0456	.0390	.0331	.0219	.0095	.0042	-.0009	-.0101	-.0108	-.0108	-.0042	M
.7000		.0554	.0449	.0357	.0245	.0121	.0036	-.0088	-.0134	-.0173	-.0134		
.8500				.0344	.0252	.0180	-.0003	-.0081	-.0147	-.0213			
.1000	.0472	.0360	.0334	.0393	.0183	.0262	.0137	.0190	.0111	.0210	.0630	.0157	D
.2500	.0551	.0485	.0406	.0321	.0308	.0269	.0045	.0190	.0150	.0203	.0196	.0183	I
.4000	.0689	.0616	.0538	.0531	.0347	.0293	.0269	.0209	.0249	.0236	.0216	.0177	F
.5500	.0886	.0748	.0656	.0557	.0446	.0367	.033[illegible]	.0314	.0262	.0262	.0262	.0111	F
.7000		.1003	.0872	.0793	.0655	.0531	.0465	.0393	.0327	.0301	.0321		
.8500				.1056	.0924	.0859	.0682	.0623	.0577	.0524			

$\alpha = 3$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0006	-.0059	-.0072	-.0078	-.0019	-.0177	-.0085	-.0131	-.0078	-.0183	-.0223	-.0216	
.2500	-.0282	-.0249	-.0223	-.0203	-.0131	-.0137	-.0059	-.0216	-.0203	-.0236	-.0262	-.0255	T
.4000	-.0452	-.0393	-.0347	-.0328	-.0262	-.0229	-.0262	-.0288	-.0354	-.0341	-.0327	-.0282	O
.5500	-.0603	-.0557	-.0525	-.0505	-.0511	-.0452	-.0367	-.0409	-.0436	-.0455	-.0449	-.0219	P
.7000		-.0760	-.0708	-.0688	-.0695	-.0715	-.0734	-.0760	-.0708	-.0636	-.0570		
.8500				-.0934	-.0928	-.0941	-.0947	-.0980	-.0993	-.1000			
.1000	.0708	.0511	.0465	.0387	.0269	.0196	.0203	.0190	.0144	.0157	.0590	.0045	
.2500	.0590	.0557	.0446	.0334	.0354	.0275	.0105	.0105	.0059	.0085	.0045	.0052	B
.4000	.0603	.0078	.0544	.0452	.0341	.0242	.0170	.0085	.0039	.0039	.0026	.0045	T
.5500	.0571	.0564	.0505	.0446	.0328	.0210	.0144	.0088	-.0009	-.0029	-.0022	.0042	M
.7000		.0636	.0590	.0511	.0354	.0255	.0163	.0039	-.0026	-.0065	-.0065		
.8500				.0501	.0170	.0232	.0127	.0042	-.0022	-.0101			
.1000	.0715	.0590	.0538	.0465	.0288	.0374	.0288	.0321	.0223	.0341	.0813	.0262	D
.2500	.0872	.0807	.0669	.0557	.0485	.0413	.0164	.0321	.0262	.0321	.0308	.0308	I
.4000	.1056	.0472	.0892	.0781	.0603	.0472	.0413	.0373	.0393	[illegible]	.0354	.0327	F
.5500	.1174	.1122	.1030	.0951	.0840	.0662	.0511	.0498	.0426	.0426	.0426	.0262	F
.7000		.1397	.1298	.1200	.1049	.0970	.0898	.0800	.0682	.0570	.0524		
.8500				.1436	.1298	.1174	.1075	.1023	.0970	.0898			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(c) Run 6 – No boundary layer trip (repeat of Run 5) (cont'd)

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0144	-.0157	-.0164	-.0177	-.0072	-.0216	-.0196	-.0183	-.0118	-.0242	-.0275	-.0262	
.2500	-.0433	-.0380	-.0367	-.0380	-.0203	-.0203	-.0105	-.0273	-.0255	-.0288	-.0315	-.0308	T
.4000	-.0616	-.0551	-.0538	-.0551	-.0551	-.0328	-.0321	-.0341	-.0400	-.0387	-.0373	-.0334	O
.5500	-.0741	-.0708	-.0695	-.0689	-.0715	-.0781	-.0662	-.0600	-.0564	-.0551	-.0544	-.0209	P
.7000		-.0885	-.0846	-.0846	-.0865	-.0885	-.0911	-.0931	-.0931	-.0924	-.0898		
.8500				-.1003	-.0997	-.1003	-.1003	-.1029	-.1023	-.0983			
.1000	.0820	.0649	.0571	.0479	.0347	.0282	.0288	.0255	.0216	.0210	.0676	.0131	
.2500	.0656	.0649	.0544	.0439	.0433	.0360	.0190	.0190	.0131	.0150	.0124	.0124	B
.4000	.0649	.0130	.0623	.0544	.0439	.0321	.0255	.0177	.0124	.0124	.0104	.0124	T
.5500	.0531	.0636	.0597	.0525	.0446	.0321	.0242	.0183	.0085	.0052	.0065	.0124	M
.7000		.0616	.0675	.0636	.0478	.0373	.0282	.0150	.0072	.0045	.0065		
.8500				.0583	.0478	.0347	.0249	.0150	.0098	.0045			
.1000	.0964	.0807	.0735	.0656	.0420	.0498	.0485	.0439	.0334	.0452	.0951	.0399	D
.2500	.1089	.1030	.0912	.0820	.0636	.0564	.0295	.0465	.0387	.0439	.0439	.0433	I
.4000	.1264	.0702	.1161	.1096	.0991	.0649	.0577	.0518	.0524	.0511	.0478	.0459	F
.5500	.1273	.1345	.1292	.1214	.1161	.1102	.0905	.0774	.0649	.0603	.0610	.0334	F
.7000		.1502	.1521	.1482	.1344	.1259	.1193	.1082	.1003	.0970	.0964		
.8500				.1587	.1475	.1351	.1252	.1180	.1121	.1029			

$\alpha = 5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0282	-.0269	-.0255	-.0288	-.0118	-.0255	-.0177	-.0223	-.0164	-.0282	-.0315	-.0295	
.2500	-.0544	-.0505	-.0505	-.0531	-.0446	-.0269	-.0144	-.0321	-.0301	-.0334	-.0360	-.0341	T
.4000	-.0695	-.0662	-.0662	-.0676	-.0721	-.0669	-.0571	-.0511	-.0505	-.0472	-.0439	-.0387	O
.5500	-.0833	-.0813	-.0813	-.0813	-.0840	-.0872	-.0820	-.0300	-.0294	-.1306	-.0287	.0023	P
.7000		-.0957	-.0924	-.0931	-.0951	-.0970	-.0990	-.0990	-.0990	-.0983	-.0997		
.8500				-.0497	-.0504	-.0510	-.0510	-.0517	-.0497	-.0419			
.1000	.0918	.0767	.0708	.0584	.0446	.0374	.0367	.0341	.0295	.0269	.0690	.0210	
.2500	.0715	.0735	.0676	.0544	.0525	.0459	.0282	.0288	.0216	.0223	.0196	.0203	B
.4000	.0649	.0242	.0721	.0662	.0544	.0413	.0347	.0268	.0216	.0196	.0183	.0209	T
.5500	.0459	.0676	.0662	.0616	.0557	.0433	.0341	.0801	.0689	.0650	.0649	.0722	M
.7000		.0570	.0688	.0741	.0583	.0478	.0387	.0249	.0183	.0144	.0190		
.8500				.1148	.1083	.0945	.0860	.0781	.0748	.0683			
.1000	.1201	.1036	.0964	.0872	.0564	.0630	.0544	.0564	.0439	.0551	.1005	.0505	D
.2500	.1260	.1240	.1181	.1076	.0971	.0728	.0626	.0610	.0518	.0557	.0557	.0544	I
.4000	.1345	.0985	.1384	.1338	.1266	.1082	.0918	.0790	.0721	.0669	.0623	.0596	F
.5500	.1292	.1489	.1476	.1430	.1397	.1306	.1161	.1102	.0983	.1936	.0957	.0498	F
.7000		.1528	.1613	.1672	.1534	.1449	.1377	.1239	.1174	.1128	.1187		
.8500				.1646	.1587	.1456	.1370	.1298	.1246	.1102			

$\alpha = 6$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0380	-.0341	-.0334	-.0413	-.0170	-.0088	-.0216	-.0262	-.0196	-.0321	-.0347	-.0321	
.2500	-.0603	-.0590	-.0590	-.0610	-.0689	-.0557	-.0190	-.0380	-.0354	-.0360	-.0393	-.0360	T
.4000	-.0761	-.0741	-.0741	-.0767	-.0774	-.0787	-.0787	-.0787	-.0793	-.0747	-.0715	-.0570	O
.5500	-.0859	-.0853	-.0846	-.0853	-.0879	-.0885	-.0918	-.0951	-.0977	-.0997	-.0997	-.0439	P
.7000		-.0957	-.0931	-.0944	-.0970	-.0983	-.0997	-.1010	-.1010	-.1016	-.1036		
.8500				-.1083	-.1083	-.1029	-.1029	-.1036	-.1010	-.0931			
.1000	.1006	.0859	.0833	.0708	.0571	.0465	.0465	.0420	.0387	.0347	.0380	.0308	
.2500	.0767	.0880	.0800	.0662	.0630	.0551	.0380	.0387	.0315	.0308	.0275	.0301	B
.4000	.0662	.0308	.0794	.0767	.0656	.0525	.0452	.0373	.0314	.0288	.0275	.0288	T
.5500	.0393	.0721	.0728	.0708	.0682	.0551	.0446	.0393	.0282	.0236	.0249	.0295	M
.7000		.0564	.0721	.0846	.0695	.0596	.0505	.0367	.0295	.0262	.0308		
.8500				.0701	.0669	.0531	.0459	.0400	.0367	.0288			
.1000	.1386	.1201	.1187	.1122	.0741	.0754	.0682	.0682	.0584	.0669	.1148	.0630	D
.2500	.1371	.1391	.1391	.1273	.1319	.1109	.0571	.0767	.0669	.0669	.0669	.0662	I
.4000	.1424	.1050	.1535	.1535	.1430	.1312	.1240	.1161	.1108	.1036	.0990	.0859	F
.5500	.1253	.1575	.1575	.1562	.1562	.1476	.1365	.1344	.1259	.1233	.1246	.0734	F
.7000		.1521	.1653	.1790	.1666	.1580	.1502	.1377	.1305	.1259	.1344		
.8500				.1785	.1692	.1561	.1489	.1436	.1377	.1220			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(c) Run 6 – No boundary layer trip (repeat of Run 5) (concl'd)

$\alpha = 7$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0439	-.0413	-.0446	-.0525	-.0301	-.0334	-.0249	-.0295	-.0216	-.0354	-.0380	-.0347	
.2500	-.0695	-.0689	-.0702	-.0721	-.0748	-.0735	-.0229	-.0590	-.0446	-.0301	-.0413	-.0380	T
.4000	-.0833	-.0813	-.0820	-.0833	-.0859	-.0899	-.0938	-.0970	-.1003	-.0997	-.0977	-.0826	O
.5500	-.0892	-.0892	-.0892	-.0899	-.0918	-.0964	-.0971	-.0997	-.1029	-.1062	-.1082	-.0818	P
.7000		-.0990	-.0977	-.0990	-.1016	-.1029	-.1043	-.1049	-.1056	-.1062	-.1075		
.8500				-.1056	-.1062	-.1069	-.1069	-.1075	-.1056	-.0977			
.1000	.1069	.0958	.0951	.0833	.0689	.0557	.0571	.0518	.0472	.0426	.0840	.0400	
.2500	.0826	.0872	.0859	.0774	.0748	.0662	.0479	.0492	.0413	.0393	.0360	.0387	B
.4000	.0649	.0387	.0872	.0859	.0774	.0643	.0557	.0478	.0413	.0387	.0367	.0380	T
.5500	.0315	.0774	.0807	.0800	.0794	.0662	.0551	.0505	.0387	.0347	.0354	.0393	M
.7000		.0551	.0780	.0918	.0800	.0701	.0610	.0472	.0413	.0360	.0413		
.8500				.0774	.0767	.0636	.0583	.0518	.0491	.0432			
.1000	.1509	.1371	.1397	.1358	.0991	.0892	.0820	.0813	.0689	.0781	.1220	.0748	D
.2500	-.1522	.1562	.1562	.1496	.1496	.1397	.0708	.1082	.0859	.0695	.0774	.0767	I
.4000	.1483	.1201	.1693	.1693	.1634	.1542	.1496	.1449	.1416	.1384	.1344	.1206	F
.5500	.1207	.1667	.1699	.1699	.1713	.1627	.1522	.1502	.1416	.1410	.1436	.1212	F
.7000		.1541	.1758	.1908	.1817	.1731	.1653	.1521	.1469	.1423	.1489		
.8500				.1830	.1830	.1705	.1653	.1594	.1548	.1410			

$\alpha = 9$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0584	-.0584	-.0623	-.0728	-.0735	-.0439	-.0328	-.0380	-.0288	-.0439	-.0472	-.0426	
.2500	-.0826	-.0826	-.0840	-.0866	-.0931	-.1050	-.0971	-.1010	-.0741	-.0584	-.0564	-.0525	T
.4000	-.0991	-.0971	-.0984	-.0997	-.0951	-.1004	-.1050	-.1121	-.1193	-.1239	-.1213	-.1134	O
.5500	-.0971	-.0977	-.0984	-.0991	-.1010	-.1030	-.1063	-.1075	-.1115	-.1134	-.1154	-.0892	P
.7000		-.1056	-.1049	-.1043	-.1062	-.1075	-.1082	-.1095	-.1102	-.1115	-.1095		
.8500				-.1102	-.1108	-.1115	-.1108	-.1121	-.1108	-.1049			
.1000	.1220	.1194	.1194	.1102	.0905	.0662	.0774	.0708	.0695	.0630	.0971	.0610	
.2500	.0905	.1023	.1056	.1023	.0991	.0892	.0682	.0794	.0630	.0597	.0564	.0590	B
.4000	.0643	.0597	.1036	.1069	.1017	.0905	.0800	.0721	.0642	.0610	.0583	.0610	T
.5500	.0164	.0846	.0971	.1010	.1030	.0905	.0807	.0754	.0623	.0570	.0583	.0629	M
.7000		.0544	.0905	.1029	.1043	.0944	.0846	.0715	.0688	.0636	.0655		
.8500				.0905	.0957	.0859	.0826	.0780	.0754	.0695			
.1000	.1804	.1778	.1818	.1831	.1640	.1102	.1102	.1089	.0984	.1069	.1443	.1036	D
.2500	.1732	.1850	.1896	.1890	.1923	.1923	.1653	.1804	.1371	.1181	.1128	.1115	I
.4000	.1634	.1568	.2021	.2067	.1968	.1909	.1850	.1843	.1836	.1849	.1797	.1744	F
.5500	.1135	.1844	.1955	.2001	.2041	.1936	.1870	.1830	.1738	.1705	.1738	.1521	F
.7000		.1600	.1954	.2072	.2105	.2020	.1928	.1810	.1790	.1751	.1751		
.8500				.2007	.2066	.1974	.1935	.1902	.1862	.1744			

$\alpha = 2$ (repeat)

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0118	.0052	.0006	.0006	.0013	-.0131	-.0032	-.0078	-.0026	-.0124	-.0164	-.0177	
.2500	-.0065	-.0065	-.0072	-.0072	-.0059	-.0072	-.0086	-.0164	-.0150	-.0190	-.0210	-.0210	T
.4000	-.0164	-.0144	-.0118	-.0124	-.0118	-.0157	-.0190	-.0219	-.0291	-.0278	-.0272	-.0226	O
.5500	-.0321	-.0308	-.0275	-.0223	-.0236	-.0262	-.0288	-.0337	-.0366	-.0383	-.0390	-.0436	P
.7000		-.0469	-.0436	-.0455	-.0416	-.0416	-.0439	-.0482	-.0538	-.0547	-.0568		
.8500				-.0751	-.0705	-.0718	-.0731	-.0757	-.0764	-.0764			
.1000	.0603	.0420	.0360	.0275	.0190	.0229	.0130	.0118	.0078	.0085	-.0092	-.0019	
.2500	.0505	.0426	.0334	.0255	.0055	.0062	.0032	.0086	.0000	-.0086	-.0019	-.0086	B
.4000	.0538	.0006	.0439	.0347	.0249	.0144	.0065	.0000	-.0036	-.0029	-.0049	-.0029	T
.5500	.0564	.0459	.0387	.0328	.0216	.0105	.0045	-.0016	-.0000	-.0114	-.0100	-.0062	M
.7000		.0573	.0455	.0370	.0252	.0134	-.0049	-.0075	-.0147	-.0183	-.0147		
.8500				.0537	.0239	.0095	-.0016	-.0101	-.0167	-.0226			
.1000	.0485	.0367	.0354	.0249	.0177	.0360	.0183	.0196	.0105	.0210	.0464	.0157	D
.2500	.0571	.0492	.0406	.0328	.0315	.0334	.0080	.0180	.0150	.0196	.0190	.0183	I
.4000	.0702	.0150	.0557	.0472	.0367	.0301	.0075	.0223	.0255	.0249	.0223	.0196	F
.5500	.0886	.0767	.0662	.0551	.0452	.0367	.0334	.0321	.0255	.0268	.0282	.0393	F
.7000		.1043	.0892	.0826	.0669	.0551	.0478	.0446	.0380	.0354	.0360		
.8500				.1088	.0944	.0813	.0715	.0655	.0896	.0537			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(d) Run 7 – With boundary layer trip (2)

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0009	-.0016	-.0016	.0049	.0022	-.0114	-.0022	-.0062	-.0009	-.0114	-.0154	-.0167	
.2500	.0111	-.0019	-.0150	-.0065	-.0059	-.0059	-.0019	-.0157	-.0137	-.0177	-.0196	-.0196	T
.4000	.0029	-.0285	-.0121	-.0121	-.0088	-.0147	-.0173	-.0209	-.0281	-.0268	-.0268	-.0222	O
.5500	-.0282	-.0190	-.0367	-.0255	-.0190	-.0255	-.0282	-.0327	-.0360	-.0367	-.0373	-.0131	P
.7000		-.0367	-.0426	-.0426	-.0432	-.0386	-.0367	-.0439	-.0498	-.0531	-.0472		
.8500				-.0760	-.0708	-.0747	-.0753	-.0773	-.0799	-.0806			
.1000	.0842	.0403	.0482	.0272	.0213	.0193	.0173	.0134	.0081	.0108	-.0075	-.0009	
.2500	.0596	.0400	.0288	.0275	.0255	.0209	.0124	.0039	.0013	.0026	-.0013	-.0013	B
.4000	.0646	.0016	.0580	.0331	.0252	.0154	-.0567	.0006	-.0026	-.0026	-.0039	-.0019	T
.5500	.0583	.0478	.0426	.0327	.0216	.0106	.0059	-.0006	-.0091	-.0098	-.0104	-.0032	M
.7000		.0557	.0793	.0465	-.0452	.0137	.0052	-.0072	-.0137	-.0170	-.0131		
.8500				.0367	-.0039	.0059	-.0019	-.0091	-.0150	-.0229			
.1000	.0852	.0419	.0498	.0223	.0190	.0308	.0196	.0196	.0091	.0223	.0078	.0157	D
.2500	.0485	.0419	.0439	.0321	.0314	.0268	.0144	.0196	.0150	.0203	.0183	.0183	I
.4000	.0616	.0301	.0701	.0452	.0341	.0301	-.0393	.0216	.0255	.0242	.0229	.0203	F
.5500	.0865	.0669	.0793	.0583	.0406	.0360	.0341	.0321	.0268	.0268	.0268	.0098	F
.7000		.0924	.1219	.0891	-.0019	.0524	.0419	.0367	.0360	.0360	.0340		
.8500				.1127	.0668	.0806	.0734	.0681	.0649	.0576			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(e) Run 8 – With boundary layer trip (4)

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0576	-.0295	.0596	.0406	.0295	.0091	.0216	.0183	.0225	.0150	.0085	.0039	
.2500	.0242	.0118	.1055	.0347	.0295	.0262	.0072	.0104	[illegible]	.0065	.0039	.0026	T
.4000	.0635	.0118	.0288	.0354	.0334	.0216	.0177	.0117	.0000	.0000	-.0006	.0019	O
.5500	.0445	.0426	.0458	.0871	.0334	.0137	.0118	.0065	-.0013	-.0045	-.0058	-.0006	P
.7000		.0570	.0760	-.0124	.0235	.0229	.0124	.0072	-.0065	-.0104	-.0058		
.8500				.0150	.0648	.0222	.0111	-.0006	-.0131	-.0170			
.1000	.0439	-.0085	-.0013	-.0026	-.0026	.0045	-.0045	-.0104	-.0131	-.0163	-.0472	-.0216	
.2500	-.0045	-.0321	-.0078	-.0131	-.0065	-.0111	-.0163	-.0216	-.0209	-.0229	-.0242	-.0229	B
.4000	-.0216	.0288	-.0203	-.0196	-.0203	-.0229	-.0255	-.0294	-.0314	-.0301	-.0301	-.0275	T
.5500	-.0458	-.0413	-.0537	-.0426	-.0308	-.0367	-.0354	-.0399	-.0439	-.0425	-.0412	-.0347	M
.7000		-.0583	-.0733	-.0779	-.0655	-.0530	.0150	-.0550	-.0589	-.0596	-.0550		
.8500				-.0891	-.0897	-.0923	-.0910	-.0923	-.0923	-.0904			
.1000	-.0137	.0209	-.0609	-.0432	-.0321	-.0045	-.0262	-.0288	-.0360	-.0314	-.0557	-.0255	D
.2500	-.0288	-.0439	-.1134	-.0478	-.0360	-.0373	-.0236	-.0321	-.0308	-.0295	-.0281	-.0255	I
.4000	-.0852	.0170	-.0491	-.0550	-.0537	-.0445	-.0432	-.0412	-.0314	-.0301	-.0294	-.0294	F
.5500	-.0904	-.0839	-.0996	-.1298	-.0642	-.0504	-.0472	-.0445	-.0425	-.0380	-.0353	-.0140	F
.7000		-.1151	-.1494	-.0655	-.0891	-.0760	.0026	-.0622	-.0524	-.0491	-.0491		
.8500				-.1041	-.1546	-.1146	-.1022	-.0917	-.0792	-.0733			

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0321	-.0347	.0360	.0196	.0157	-.0013	.0085	.0052	.0098	.0006	-.0039	-.0078	
.2500	.0006	-.0059	.1022	.0144	.0111	.0078	-.0052	-.0026	-.0026	-.0065	-.0085	-.0104	T
.4000	.0393	-.0104	.0085	.0163	.0124	.0032	.0000	-.0049	-.0140	-.0134	-.0140	-.0095	O
.5500	.0229	.0091	.0078	.0445	.0104	-.0078	-.0085	-.0137	-.0163	-.0203	-.0216	-.0065	P
.7000		.0324	.0540	-.0311	-.0016	-.0036	-.0114	-.0206	-.0271	-.0291	-.0252		
.8500				-.0163	.0013	-.0190	-.0203	-.0281	-.0373	-.0412			
.1000	.0642	.0209	.0170	.0098	.0078	-.0059	.0039	.0013	-.0032	-.0032	-.0124	-.0124	
.2500	.0301	-.0111	.0327	.0059	.0085	.0039	-.0019	-.0098	-.0091	-.0104	-.0131	-.0131	B
.4000	.0301	-.0098	-.0118	.0065	.0019	-.0039	-.0085	-.0147	-.0180	-.0167	-.0180	-.0153	T
.5500	.0236	.0249	-.0059	.0111	-.0032	-.0131	-.0150	-.0203	-.0262	-.0262	-.0262	-.0190	M
.7000		.0232	-.0151	-.0389	-.0095	-.0167	-.0226	-.0324	-.0357	-.0396	-.0337		
.8500				-.0334	-.0144	-.0255	-.0301	-.0393	-.0419	-.0504			
.1000	.0321	.0557	-.0190	-.0098	-.0078	-.0045	-.0045	-.0039	-.0131	-.0039	-.0085	-.0045	D
.2500	.0295	-.0052	-.0694	-.0085	-.0026	-.0039	.0032	-.0072	-.0065	-.0039	-.0045	-.0026	I
.4000	-.0091	.0006	-.0203	-.0098	-.0104	-.0072	-.0085	-.0098	-.0039	-.0032	-.0039	-.0058	F
.5500	.0006	.0157	-.0137	-.0334	-.0137	-.0052	-.0065	-.0065	-.0098	-.0058	-.0045	-.0124	F
.7000		-.0091	-.0694	-.0078	-.0078	-.0131	-.0111	-.0117	-.0085	-.0104	-.0085		
.8500				-.0170	-.0157	-.0065	-.0098	-.0111	-.0045	-.0091			

$\alpha = +2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0013	-.0393	.0098	.0032	-.0636	-.0118	-.0019	-.0065	-.0006	-.0118	-.0150	-.0163	
.2500	-.0236	-.0249	.0223	-.0039	-.0052	-.0059	-.0203	-.0157	-.0137	-.0177	-.0203	-.0203	T
.4000	-.0019	-.0301	-.0209	-.0085	-.0098	-.0144	-.0170	-.0196	-.0275	-.0262	-.0255	-.0216	O
.5500	-.0242	.0262	-.0596	-.0229	-.0163	-.0295	-.0288	-.0327	-.0354	-.0367	-.0373	-.0104	P
.7000		-.0262	-.0019	-.0649	-.0413	-.0347	-.0367	-.0452	-.0491	-.0511	-.0465		
.8500				-.0740	-.0734	-.0819	-.0767	-.0734	-.0118	-.0118			
.1000	.0793	.0478	.0380	.0275	.0216	.0196	.0177	.0144	.0085	.0111	.0183	-.0013	
.2500	.0557	.0059	.0642	.0255	.0255	.0203	.0124	.0039	.0013	.0026	-.0013	-.0019	B
.4000	.0590	.0019	.0144	.0301	.0255	.0163	.0098	.0013	-.0019	-.0013	-.0032	-.0013	T
.5500	.0557	.0577	.0373	.0452	.0223	.0098	.0052	.0000	-.0085	-.0098	-.0098	-.0039	M
.7000		.0590	.0393	-.0065	.0255	.0150	.0052	-.0065	-.0131	-.0137	-.0124		
.8500				.0045	.0852	.0255	.0006	-.0111	-.0118	-.0816			
.1000	.0780	.0872	.0282	.0242	.0852	.0314	.0196	.0209	.0091	.0229	.0334	.0150	D
.2500	.0793	.0308	.0419	.0295	.0308	.0262	.0327	.0196	.0150	.0203	.0190	.0183	I
.4000	.0610	.0321	.0354	.0387	.0354	.0308	.0268	.0209	.0255	.0249	.0222	.0203	F
.5500	.0800	.0314	.0970	.0682	.0387	.0393	.0341	.0327	.0268	.0268	.0275	.0065	F
.7000		.0852	.0413	.0583	.0668	.0498	.0419	.0366	.0360	.0354	.0340		
.8500				.0786	.1586	.1075	.0753	.0622	.0000	-.0098			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(e) Run 8 – With boundary layer trip (4) (concl'd)

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0229	-.0557	-.0183	-.0085	-.0078	-.0216	-.0131	-.0183	-.0118	-.0249	-.0275	-.0255	
.2500	-.0491	-.0590	-.0393	-.0255	-.0203	-.0209	-.0308	-.0268	-.0255	-.0295	-.0321	-.0314	T
.4000	-.0596	-.0688	-.0642	-.0537	-.0354	-.0340	-.0340	-.0344	-.0402	-.0389	-.0383	-.0344	O
.5500	-.0773	-.0826	-.0780	-.0747	-.0681	-.0642	-.0550	-.0540	-.0534	-.0534	-.0527	-.0265	P
.7000		-.0927	-.0828	-.0887	-.0881	-.0887	-.0861	-.0842	-.0822	-.0796	-.0789		
.8500				-.1025	-.0999	-.1025	-.1018	-.1032	-.1025	-.0986			
.1000	.0983	.0708	.0576	.0465	.0380	.0262	.0308	.0268	.0222	.0209	.0478	.0131	
.2500	.0701	.0255	.0871	.0432	.0426	.0373	.0301	.0203	.0144	.0163	.0131	.0131	B
.4000	.1049	.0157	.0386	.0504	.0439	.0327	.0262	.0180	.0134	.0127	.0114	.0134	T
.5500	.0531	.0701	.0649	.0681	.0465	.0327	.0255	.0186	.0095	.0062	.0075	.0127	M
.7000		.0599	.0697	.0173	.0494	.0383	.0271	.0153	.0088	.0055	.0068		
.8500				.0291	.1457	.0566	.0298	.0134	.0134	.0062			
.1000	.1212	.1265	.0760	.0550	.0458	.0478	.0439	.0452	.0340	.0458	.0753	.0386	D
.2500	.1193	.0845	.1265	.0688	.0629	.0583	.0609	.0472	.0399	.0458	.0452	.0445	I
.4000	.1645	.0845	.1029	.1042	.0793	.0668	.0603	.0524	.0537	.0517	.0498	.0478	F
.5500	.1304	.1527	.1429	.1429	.1147	.0970	.0806	.0727	.0629	.0596	.0602	.0393	F
.7000		.1526	.1526	.1061	.1376	.1271	.1133	.0996	.0910	.0851	.0858		
.8500				.1317	.2457	.1592	.1317	.1166	.1159	.1048			

$\alpha = 6$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0550	-.0708	-.0419	-.0242	-.0209	-.0314	-.0249	-.0354	-.0229	-.0327	-.0347	-.0308	
.2500	-.0681	-.0767	-.0701	-.0622	-.0491	-.0458	-.0498	-.0426	-.0399	-.0406	-.0419	-.0386	T
.4000	-.0793	-.0786	-.0747	-.0760	-.0786	-.0786	-.0780	-.0756	-.0750	-.0697	-.0658	-.0547	O
.5500	-.0826	-.0845	-.0819	-.0819	-.0845	-.0885	-.0891	-.0920	-.0953	-.0973	-.0979	-.0442	P
.7000		-.0927	-.0907	-.0940	-.0933	-.0946	-.0973	-.0979	-.0979	-.0979	-.0999		
.8500				-.0986	-.0973	-.1012	-.1005	-.1005	-.0966	-.0881			
.1000	.1147	.0911	.0793	.0681	.0596	.0367	.0472	.0432	.0380	.0347	.0773	.0301	
.2500	.0786	.0380	.1121	.0655	.0609	.0550	.0491	.0386	.0314	.0308	.0281	.0301	B
.4000	.0727	.0301	.0563	.0701	.0649	.0531	.0452	.0383	.0324	.0298	.0285	.0298	T
.5500	.0399	.0806	.0832	.0826	.0681	.0550	.0452	.0396	.0291	.0245	.0258	.0306	M
.7000		.0586	.0783	.0455	.0717	.0619	.0507	.0376	.0306	.0258	.0324		
.8500				.0475	.1713	.0769	.0507	.0370	.0389	.0311			
.1000	.1698	.1619	.1212	.0924	.0806	.0681	.0721	.0786	.0609	.0675	.1121	.0609	D
.2500	.1468	.1147	.1822	.1278	.1101	.1009	.0989	.0812	.0714	.0714	.0701	.0688	I
.4000	.1521	.1088	.1311	.1462	.1435	.1317	.1232	.1140	.1074	.0996	.0943	.0845	F
.5500	.1226	.1652	.1652	.1645	.1527	.1435	.1344	.1317	.1245	.1218	.1238	.0747	F
.7000		.1513	.1690	.1395	.1651	.1566	.1480	.1356	.1284	.1238	.1323		
.8500				.1461	.2686	.1782	.1513	.1376	.1356	.1192			

$\alpha = 9$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0760	-.0799	-.0609	-.0635	-.0603	-.0426	-.0314	-.0373	-.0452	-.0426	-.0465	-.0399	
.2500	-.0806	.5127	-.0799	-.0826	-.0904	-.0996	-.0963	-.1022	-.0786	-.0616	-.0557	-.0511	T
.4000	-.0898	-.0911	-.0891	-.0904	-.0930	-.0983	-.1055	-.1087	-.1159	-.1199	-.1192	-.1127	O
.5500	-.0957	-.0976	-.0976	-.0970	-.0989	-.1016	-.1042	-.1084	-.1097	-.1117	-.1143	-.0815	P
.7000		-.1035	-.1028	-.1048	-.1048	-.1054	-.1068	-.1074	-.1061	-.1068	-.1068		
.8500				-.1084	-.1077	-.1110	-.1097	-.1104	-.1084	-.1025			
.1000	.1265	.1239	.1134	.1068	.0957	.0701	.0793	.0767	.0629	.0878	.0616	.0681	
.2500	.0924	.0629	.1468	.1029	.0963	.0898	.0826	.0734	.0635	.0603	.0570	.0603	B
.4000	.0603	.0747	.1022	.1009	.0984	.0812	.0800	.0727	.0648	.0609	.0589	.0615	T
.5500	.0190	.0944	.1101	.1206	.1035	.0911	.0812	.0750	.0619	.0632	.0632	.0625	M
.7000		.0511	.1009	.0688	.1068	.0969	.0858	.0714	.0688	.0642	.0733		
.8500				.0730	.2126	.1143	.0861	.0743	.0743	.0697			
.1000	.2025	.2038	.1743	.1704	.1560	.1127	.1108	.1140	.1081	.1304	.1081	.1081	D
.2500	.1730	-.4497	.2268	.1855	.1868	.1894	.1789	.1757	.1422	.1219	.1127	.1114	I
.4000	.1501	.1658	.1914	.1914	.1855	.1796	.1055	.1815	.1808	.1808	.1782	.1743	F
.5500	.1147	.1920	.2078	.2176	.2025	.1987	.1855	.1815	.1716	.1749	.1795	.1441	F
.7000		.1546	.2037	.1736	.2116	.2084	.1986	.1788	.1749	.1710	.1782		
.8500				.1815	.3204	.2254	.1959	.1847	.1828	.1723			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(f) Run 9 – No boundary layer trip - all gaps sealed

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0111	.0032	-.0006	.0000	.0013	-.0144	-.0026	-.0078	-.0032	-.0150	-.0163	-.0177	
.2500	-.0072	-.0072	-.0078	-.0078	-.0059	-.0078	-.0137	-.0170	-.0183	-.0216	-.0222	-.0216	T
.4000	-.0183	-.0170	-.0137	-.0131	-.0111	-.0170	-.0183	-.0222	-.0308	-.0295	-.0281	-.0242	O
.5500	-.0347	-.0340	-.0301	-.0262	-.0262	-.0308	-.0308	-.0340	-.0380	-.0406	-.0406	-.0314	P
.7000		-.0531	-.0445	-.0478	-.0445	-.0249	-.0458	-.0485	-.0531	-.0557	-.0511		
.8500				-.0786	-.0740	-.0747	-.0760	-.0786	-.0806	-.0812			
.1000	.0590	.0439	.0393	.0275	.0216	.0190	.0170	.0131	.0078	.0052	.0524	-.0026	
.2500	.0531	.0452	.0367	.0281	.0262	.0203	.0131	.0032	.0006	.0013	-.0019	-.0013	B
.4000	.0570	.0000	.0472	.0367	.0255	.0157	.0098	.0013	-.0032	-.0026	-.0039	-.0013	T
.5500	.0557	.0478	.0413	.0347	.0229	.0111	.0052	.0000	-.0085	-.0098	-.0091	-.0026	M
.7000		.0517	.0485	.0393	.0262	.0150	.0065	-.0059	-.0131	-.0163	-.0124		
.8500				.0347	.0262	.0111	.0000	-.0072	-.0144	-.0196			
.1000	.0478	.0406	.0399	.0275	.0203	.0334	.0196	.0209	.0111	.0203	.0688	.0150	D
.2500	.0603	.0524	.0445	.0360	.0321	.0281	.0268	.0203	.0190	.0229	.0203	.0203	I
.4000	.0753	.0170	.0609	.0498	.0367	.0327	.0281	.0236	.0275	.0268	.0242	.0229	F
.5500	.0904	.0819	.0714	.0609	.0491	.0419	.0360	.0340	.0295	.0308	.0314	.0288	F
.7000		.1049	.0930	.0871	.0708	.0399	.0524	.0426	.0399	.0393	.0386		
.8500				.1134	.1003	.0858	.0760	.0714	.0662	.0616			

TABLE XIII (continued)

Flat Arrow Wing Pressure Data

(g) Run 10 – No boundary layer trip - reduced end gaps to .010

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0380	.0275	.0190	.0190	.0151	-.0019	.0078	.0039	.0085	.0000	-.0045	-.0085	
.2500	.0282	.0269	.0216	.0170	.0091	.0078	-.0006	-.0032	-.0032	-.0065	-.0091	-.0111	T
.4000	.0354	.0282	.0256	.0170	.0118	.0019	-.0006	-.0059	-.0157	-.0144	-.0144	-.0111	O
.5500	.0308	.0262	.1620	.0170	.0098	.0013	-.0091	-.0150	-.0183	-.0216	-.0229	.3622	P
.7000		.0315	.0295	.0124	.0026	-.0039	-.0118	-.0210	-.0295	-.0321	-.0275		
.8500				.0078	-.0072	-.0150	-.0229	-.0308	-.0393	-.0426			
.1000	.0334	.0210	.0144	.0118	.0072	.0065	.0026	.0000	-.0039	-.0032	.0197	-.0137	
.2500	.0249	.0203	.0151	.0065	.0026	.0032	-.0019	-.0098	-.0098	-.0052	-.0131	-.0131	B
.4000	.0242	-.0098	.0144	.0091	.0026	-.0045	-.0078	-.0150	-.0190	-.0170	-.0177	-.0150	T
.5500	.0249	.0085	.0078	.0039	-.0026	-.0118	-.0137	-.0203	-.0269	-.0262	-.0262	-.0190	M
.7000		.0091	.0032	-.0006	-.0078	-.0150	-.0196	-.0282	-.0360	-.0400	-.0347		
.8500				-.0124	-.0183	-.0282	-.0341	-.0400	-.0459	-.0505			
.1000	-.0045	-.0065	-.0045	-.0072	-.0078	.0085	-.0052	-.0039	-.0124	-.0032	.0242	-.0052	D
.2500	-.0032	-.0065	-.0065	-.0105	-.0065	-.0045	-.0013	-.0065	-.0065	.0013	-.0039	-.0019	I
.4000	-.0111	-.0380	-.0111	-.0078	-.0091	-.0065	-.0072	-.0091	-.0032	-.0026	-.0032	-.0039	F
.5500	-.0059	-.0177	-.1542	-.0131	-.0124	-.0131	-.0045	-.0052	-.0085	-.0045	-.0032	-.3813	F
.7000		-.0223	-.0262	-.0131	-.0105	-.0111	-.0078	-.0072	-.0065	-.0078	-.0072		
.8500				-.0203	-.0111	-.0131	-.0111	-.0091	-.0065	-.0078			

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0137	.0072	.0032	.0019	.0019	-.0124	-.0032	-.0078	-.0026	-.0124	-.0164	-.0177	
.2500	-.0059	-.0059	-.0065	-.0078	-.0065	-.0072	-.0164	-.0164	-.0151	-.0183	-.0210	-.0210	T
.4000	-.0177	-.0157	-.0131	-.0131	-.0105	-.0157	-.0177	-.0216	-.0288	-.0275	-.0269	-.0223	O
.5500	-.0328	-.0321	-.0282	-.0242	-.0236	-.0229	-.0302	-.2931	-.2964	-.2977	-.2977	-.2578	P
.7000		-.0472	-.0439	-.0452	-.0420	-.0420	-.0439	-.0479	-.0518	-.0544	-.0498		
.8500				-.3350	-.3304	-.3317	-.3330	-.3356	-.3369	-.3317			
.1000	.0558	.0433	.0361	.0288	.0210	.0111	.0059	.0124	.0085	.0105	.0499	-.0032	
.2500	.0525	.0453	.0354	.0269	.0242	.0190	.0124	.0026	.0000	.0019	-.0019	-.0026	B
.4000	.0545	.0013	.0453	.0341	.0242	.0151	.0091	.0006	-.0039	-.0026	-.0045	-.0026	T
.5500	.0604	.0472	.0439	.0334	.0229	.0098	.0052	-.2611	-.2696	-.2702	-.2702	-.2637	M
.7000		.0571	.0479	.0380	.0275	.0144	.0059	-.0065	-.0137	-.0177	-.0137		
.8500				-.2271	-.2349	-.2500	-.2611	-.2683	-.2755	-.2807			
.1000	.0420	.0361	.0328	.0269	.0190	.0236	.0091	.0203	.0111	.0229	.0663	.0144	D
.2500	.0584	.0512	.0420	.0348	.0308	.0262	.0298	.0190	.0151	.0203	.0190	.0183	I
.4000	.0722	.0170	.0584	.0472	.0348	.0308	.0269	.0223	.0249	.0249	.0223	.0196	F
.5500	.0932	.0794	.0722	.0577	.0466	.0328	.0354	.0320	.0268	.0274	.0274	-.0058	F
.7000		.1043	.0918	.0833	.0695	.0564	.0498	.0413	.0380	.0367	.0360		
.8500				.1078	.0954	.0817	.0719	.0673	.0614	.0509			

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0134	-.0147	-.0147	-.0160	-.0075	-.0213	-.0134	-.0187	-.0121	-.0246	-.0278	-.0272	
.2500	-.0446	-.0393	-.0380	-.0380	-.0203	-.0196	-.0269	-.0275	-.0255	-.0288	-.0315	-.0308	T
.4000	-.0633	-.0567	-.0554	-.0561	-.0567	-.0338	-.0324	-.0347	-.0413	-.0393	-.0380	-.0341	O
.5500	-.0754	-.0715	-.0702	-.0695	-.0721	-.0728	-.0702	-.0603	-.0577	-.0577	-.0570	-.0209	P
.7000		-.0924	-.0885	-.0879	.5969	-.0918	-.0931	-.0924	-.0911	-.0892	-.0865		
.8500				-.1029	-.1016	-.1023	-.1029	-.1036	-.1036	-.0997			
.1000	.0758	.0653	.0554	.0495	.0370	.0298	.0246	.0252	.0219	.0206	.0685	.0121	
.2500	.0676	.0676	.0571	.0465	.0420	.0360	.0308	.0196	.0137	.0157	.0124	.0118	B
.4000	.0653	.0147	.0653	.0541	.0436	.0331	.0259	.0177	.0118	.0118	.0104	.0124	T
.5500	.0564	.0643	.0662	.0525	.0459	.0328	.0249	.0183	.0085	.0059	.0078	.0131	M
.7000		.0610	.0682	.0636	.5969	.0373	.0282	.0150	.0078	.0052	.0065		
.8500				.0570	.0478	.0341	.0249	.0157	.0104	.0045			
.1000	.0892	.0800	.0702	.0656	.0446	.0511	.0380	.0439	.0341	.0452	.0964	.0393	D
.2500	.1122	.1069	.0951	.0846	.0623	.0557	.0577	.0472	.0393	.0446	.0439	.0426	I
.4000	.1286	.0715	.1207	.1102	.1004	.0669	.0584	.0524	.0531	.0511	.0485	.0465	F
.5500	.1319	.1358	.1365	.1220	.1181	.1056	.0951	.0787	.0662	.0636	.0549	.0341	F
.7000		.1534	.1567	.1515	.0000	.1292	.1213	.1075	.0990	.0944	.0931		
.8500				.1600	.1495	.1364	.1279	.1193	.1141	.1063			

TABLE XIII (concluded)

Flat Arrow Wing Pressure Data

(h) Run 11 – No boundary layer trip - wing waxed to fairing

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0347	.0308	.0242	.0216	.0118	-.0026	.0104	-.0006	.0065	-.0072	-.0052	-.0072	
.2500	.0288	.0314	.0157	.0131	.0085	.0065	-.0006	-.0059	-.0065	-.0111	-.0118	-.0111	T
.4000	.0327	.0268	.0262	.0190	.0124	.0006	-.0006	-.0078	-.0170	-.0170	-.0209	-.0124	O
.5500	.0327	.0268	.0209	.0183	.0085	-.0013	-.0078	-.0177	-.0209	-.0229	-.0255	-.0380	P
.7000		.0288	.0268	.0085	.0091	-.0019	-.0091	-.0229	-.0321	-.0334	-.0281		
.8500				.0091	-.0039	-.0144	-.0236	-.0314	-.0413	-.0452			
.1000	.0334	.0131	.0157	.0111	.0072	.0085	.0045	.0000	-.0059	-.0098	.0190	-.0144	
.2500	.0216	.0183	.0137	.0065	.0085	.0039	-.0006	-.0098	-.0118	-.0144	-.0163	-.0150	B
.4000	.0229	-.0131	.0144	.0091	.0039	-.0039	-.0078	-.0150	-.0203	-.0190	-.0190	-.0242	T
.5500	.0262	.0078	.0078	.0052	-.0026	-.0118	-.0137	-.0209	-.0275	-.0288	-.0281	-.0216	M
.7000		.0078	.0019	-.0013	-.0078	-.0144	-.0203	-.0288	-.0367	-.0347	-.0301		
.8500				-.0118	-.0183	-.0281	-.0340	-.0406	-.0465	-.0504			
.1000	-.0013	-.0177	-.0085	-.0104	-.0045	.0111	-.0059	.0006	-.0124	-.0026	.0242	-.0072	D
.2500	-.0072	-.0131	-.0019	-.0065	.0000	-.0026	.0000	-.0039	-.0052	-.0032	-.0045	-.0039	I
.4000	-.0098	-.0400	-.0118	-.0098	-.0085	-.0065	-.0072	-.0072	-.0032	-.0019	.0019	-.0118	F
.5500	-.0065	-.0190	-.0131	-.0131	-.0111	-.0104	-.0059	-.0032	-.0065	-.0059	-.0026	.0163	F
.7000		-.0209	-.0249	-.0098	-.0170	-.0124	-.0111	-.0059	-.0045	-.0013	-.0019		
.8500				-.0209	-.0144	-.0137	-.0104	-.0091	-.0052	-.0052			

$\alpha = 2$

y/b \ x/c	.0100	.0750	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0183	.0150	.0104	.0039	.0039	-.0150	-.0039	-.0111	-.0039	-.0190	-.0177	-.0183	
.2500	-.0026	-.0059	-.0104	-.0091	-.0052	-.0072	-.0157	-.0177	-.0190	-.0223	-.0236	-.0229	T
.4000	-.0209	-.0196	-.0137	-.0111	-.0111	-.0163	-.0190	-.0232	-.0317	-.0298	-.0298	-.0252	O
.5500	-.0308	-.0308	-.0275	-.0236	-.0229	-.0275	-.0308	-.0327	-.0386	-.0406	-.0406	-.0275	P
.7000		-.0468	-.0435	-.0455	-.0449	-.0442	-.0455	-.0488	-.0521	-.0567	-.0540		
.8500				-.0773	-.0727	-.0740	-.0760	-.0773	-.0793	-.0812			
.1000	.0531	.0426	.0400	.0314	.0183	.0216	.0183	.0131	.0059	.0026	.0491	-.0032	
.2500	.0491	.0446	.0347	.0242	.0255	.0183	.0144	.0032	-.0006	-.0019	-.0052	-.0032	B
.4000	.0537	-.0013	.0452	.0334	.0249	.0150	.0091	.0003	-.0055	-.0049	-.0075	-.0042	T
.5500	-.0059	.0472	.0439	.0341	.0229	.0111	.0052	-.0013	-.0104	-.0118	-.0118	-.0059	M
.7000		.0560	.0468	.0383	.0278	.0134	.0055	-.0075	-.0140	-.0193	-.0147		
.8500				.0327	.0242	.0098	-.0006	-.0085	-.0150	-.0209			
.1000	.0347	.0275	.0295	.0275	.0144	.0367	.0223	.0242	.0098	.0216	.0669	.0150	D
.2500	.0518	.0505	.0452	.0334	.0308	.0255	.0301	.0209	.0183	.0203	.0183	.0196	I
.4000	.0747	.0183	.0590	.0446	.0360	.0314	.0282	.0236	.0262	.0249	.0222	.0209	F
.5500	.0249	.0780	.0715	.0577	.0459	.0387	.0360	.0314	.0281	.0288	.0288	.0216	F
.7000		.1029	.0904	.0839	.0727	.0576	.0511	.0413	.0380	.0373	.0393		
.8500				.1101	.0970	.0839	.0753	.0688	.0642	.0603			

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0186	-.0167	-.0121	-.0095	-.0088	-.0265	-.0154	-.0219	-.0134	-.0298	-.0285	-.0285	
.2500	-.0518	-.0511	-.0432	-.0334	-.0196	-.0216	-.0275	-.0288	-.0301	-.0334	-.0347	-.0334	T
.4000	-.0816	-.0744	-.0692	-.0600	-.0364	-.0337	-.0357	-.0367	-.0439	-.0426	-.0413	-.0367	O
.5500	-.0819	-.0780	-.0760	-.0754	-.0715	-.0636	-.0603	-.0590	-.0590	-.0590	-.0590	-.0327	P
.7000		-.0957	-.0904	-.0898	-.0917	-.0964	-.0937	-.0898	-.0871	-.0852	-.0832		
.8500				-.1075	-.1062	-.1068	-.1068	-.1081	-.1075	-.1022			
.1000	.0764	.0646	.0600	.0501	.0291	.0377	.0291	.0259	.0200	.0167	.0685	.0095	
.2500	.0669	.0642	.0564	.0426	.0439	.0341	.0321	.0190	.0131	.0118	.0098	.0111	B
.4000	.0639	.0127	.0619	.0560	.0423	.0324	.0259	.0177	.0111	.0104	.0085	.0104	T
.5500	.0498	.0610	.0629	.0531	.0465	.0334	.0242	.0183	.0085	.0052	.0065	.0104	M
.7000		.0583	.0668	.0635	.0511	.0373	.0281	.0150	.0078	.0052	.0059		
.8500				.0557	.0472	.0327	.0236	.0157	.0111	.0045			
.1000	.0951	.0813	.0721	.0596	.0380	.0662	.0646	.0678	.0334	.0465	.0970	.0380	D
.2500	.1187	.1154	.0997	.0760	.0636	.0557	.0596	.0678	.0432	.0452	.0646	.0446	I
.4000	.1456	.0872	.1311	.1161	.0787	.0662	.0616	.0544	.0550	.0531	.0498	.0472	F
.5500	.1318	.1390	.1390	.1285	.1180	.0970	.0846	.0773	.0675	.0662	.0635	.0432	F
.7000		.1540	.1573	.1534	.1429	.1317	.1219	.1049	.0950	.0904	.0891		
.8500				.1632	.1534	.1396	.1304	.1239	.1186	.1068			

TABLE XIV

Flat Double Delta Wing Pressure Data

(a) Bad Pressure Taps

y/b \ x/c	.010	.025	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	
.10	--	--	--	--	--	--	--	--	--	--	--	--	
.25	--	--	--	--	--	--	--	--	--	--	--	--	T
.40	--	--	--	--	--	--	--	--	--	--	--	--	O
.50		--	--	--	--	--	--	--	--	--	--		P
.65			--	--	--	--	--	--	--	xxxx			
.80				--	--	--	--	--	--				
.10	--	--	--	--	--	--	--	--	--	--	--	--	B
.25	--	--	--	--	--	--	—	--	--	--	--	--	T
.40	--	--	--	--	--	--	--	--	--	--	--	--	M
.50		--	--	--	--	--	--	--	--	--	--		
.65			--	--	--	--	--	--	--	--			
.80				--	--	--	--	xxxx	--				
.10	--	--	--	--	--	--	--	--	--	--	--	--	D
.25	--	--	--	--	--	--	--	--	--	--	--	--	I
.40	--	--	--	--	--	--	--	--	--	--	--	--	F
.50		--	--	--	--	--	--	--	--	--	--		F
.65			--	--	--	--	--	--	--	xxxx			
.80				--	--	--	--	xxxx	--				

TABLE XIV (Continued)

Flat Double Delta Wing Pressure Data

(b) Run 17 – No boundary layer trip - bad dew point for α = + 3 to 5

α = −2

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0498	.0465	.0465	.0301	.0222	.0196	.0176	.0137	.0085	.0111	.0065	.0072	
.2500	.0589	.0511	.0419	.0275	.0307	.0222	.0150	.0065	.0006	-.0045	-.0013	.0032	T
.4000	.0537	.0537	.0465	.0445	.0327	.0288	.0183	.0068	-.0009	-.0068	-.0068	-.0029	O
.5000		.1395	.1094	.0996	.0589	.0380	.0307	.0173	.0029	-.0062	-.0121	-.0088	P
.6500			.1399	.1169	.0907	.0691	.0461	.0409	.0219	.0180	.0022		
.8000				.1497	.1156	.0973	.0750	.0540	.0350	.0258			
.1000	-.0111	-.0124	-.0104	-.0065	-.0072	-.0072	-.0111	-.0150	-.0176	-.0176	-.0216	-.0222	
.2500	-.0340	-.0275	-.0229	-.0216	-.0190	-.0196	-.0255	-.0281	-.0340	-.0294	-.0314	-.0281	B
.4000	-.0537	-.0524	-.0504	-.0504	-.0524	-.0530	-.0478	-.0481	-.0507	-.0547	-.0547	-.0507	T
.5000		-.0098	-.0157	-.0321	-.0530	.0307	-.0576	-.0612	-.0632	-.0638	-.0632	-.0625	M
.6500			.0232	.0173	-.0009	-.0180	-.0330	-.0468	-.0566	-.0638	-.0684		
.8000				.0330	.0199	.0068	-.0114	.0068	-.0311	-.0350			
.1000	-.0609	-.0589	-.0570	-.0366	-.0294	-.0268	-.0288	-.0288	-.0262	-.0288	-.0281	-.0294	D
.2500	-.0930	-.0786	-.0648	-.0491	-.0498	-.0419	-.0606	-.0347	-.0347	-.0249	-.0301	-.0314	I
.4000	-.1074	-.1061	-.0969	-.0950	-.0851	-.0819	-.0661	-.0550	-.0498	-.0478	-.0478	-.0478	F
.5000		-.1494	-.1251	-.1317	-.1120	-.0072	-.0884	-.0786	-.0661	-.0576	-.0511	-.0537	F
.6500			-.1166	-.0996	-.0917	-.0871	-.0792	-.0878	-.0786	-.0819	-.0707		
.8000				-.1166	-.0956	-.0904	-.0864	-.0471	-.0661	-.0609			

α = −1

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0399	.0366	.0301	.0222	.0104	.0137	.0104	.0072	.0019	.0039	.0000	-.0006	
.2500	.0471	.0386	.0314	.0242	.0196	.0131	.0072	-.0019	-.0072	-.0117	-.0085	-.0039	T
.4000	.0432	.0412	.0334	.0314	.0209	.0150	.0058	-.0052	-.0111	-.0176	-.0176	-.0124	O
.5000		.1100	.0832	.0688	.0386	.0216	.0144	.0029	-.0088	-.0167	-.0232	-.0212	P
.6500			.1140	.0943	.0701	.0504	.0294	.0216	.0052	.0058	-.0111		
.8000				.1222	.0927	.0763	.0560	.0370	.0186	.0108			
.1000	.0078	.0026	.0006	-.0006	-.0019	-.0019	-.0058	-.0098	-.0137	-.0124	-.0163	-.0176	
.2500	-.0098	-.0072	-.0045	-.0052	-.0072	-.0117	-.0196	-.0216	-.0281	-.0235	-.0262	-.0222	B
.4000	-.0327	-.0327	-.0255	-.0209	-.0229	-.0249	-.0327	-.0393	-.0380	-.0465	-.0458	-.0412	T
.5000		.0176	.0098	-.0098	-.0294	.0340	-.0334	-.0409	-.0475	-.0547	-.0540	-.0540	M
.6500			.0478	.0393	.0176	-.0026	-.0190	-.0334	-.0432	-.0511	-.0550		
.8000				.0547	.0383	.0226	.0029	.0121	-.0180	-.0206			
.1000	-.0321	-.0340	-.0294	-.0229	-.0124	-.0157	-.0163	-.0170	-.0157	-.0163	-.0163	-.0170	D
.2500	-.0570	-.0458	-.0360	-.0294	-.0268	-.0249	-.0268	-.0196	-.0209	-.0117	-.0176	-.0183	I
.4000	-.0760	-.0740	-.0589	-.0524	-.0439	-.0399	-.0386	-.0340	-.0268	-.0288	-.0281	-.0288	F
.5000		-.0923	-.0733	-.0786	-.0681	.0124	-.0478	-.0439	-.0386	-.0360	-.0307	-.0327	F
.6500			-.0661	-.0550	-.0524	-.0530	-.0484	-.0550	-.0484	-.0570	-.0439		
.8000				-.0674	-.0543	-.0537	-.0530	-.0249	-.0366	-.0314			

α = 0

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0288	.0249	.0222	.0144	.0085	.0085	.0052	.0006	-.0026	-.0026	-.0058	-.0065	
.2500	.0311	.0252	.0199	.0173	.0108	.0042	-.0009	-.0095	-.0134	-.0173	-.0147	-.0108	T
.4000	.0255	.0242	.0183	.0163	.0078	.0019	-.0072	-.0176	-.0222	-.0275	-.0275	-.0222	O
.5000		.0743	.0534	.0416	.0173	.0029	-.0029	-.0121	-.0206	-.0285	-.0350	-.0330	P
.6500			.0864	.0701	.0491	.0301	.0104	.0032	-.0124	.0019	-.0242		
.8000				.0940	.0697	.0560	.0376	.0206	.0036	-.0036			
.1000	.0229	.0157	.0137	.0058	.0045	.0032	.0013	-.0039	-.0091	-.0065	-.0104	-.0117	
.2500	.0134	.0134	.0121	.0095	.0036	-.0029	-.0121	-.0147	-.0212	-.0173	-.0199	-.0153	B
.4000	.0032	.0026	.0039	.0072	-.0052	-.0078	-.0170	-.0262	-.0307	-.0373	-.0373	-.0327	T
.5000		.0507	.0402	.0193	-.0016	.0317	-.0153	-.0245	-.0344	-.0402	-.0435	-.0435	M
.6500			.0760	.0635	.0380	.0144	-.0032	-.0183	-.0268	-.0347	-.0386		
.8000				.0763	.0579	.0416	.0199	.0193	-.0016	-.0068			
.1000	-.0058	-.0091	-.0085	-.0085	-.0039	-.0052	-.0039	-.0045	-.0065	-.0039	-.0045	-.0052	D
.2500	-.0176	-.0117	-.0078	-.0078	-.0072	-.0072	-.0111	-.0052	-.0078	.0000	-.0052	-.0045	I
.4000	-.0222	-.0216	-.0144	-.0091	-.0131	-.0098	-.0098	-.0085	-.0085	-.0098	-.0098	-.0104	F
.5000		-.0235	-.0131	-.0222	-.0190	.0288	-.0124	-.0134	-.0137	-.0117	-.0085	-.0104	F
.6500			-.0104	-.0065	-.0111	-.0157	-.0137	-.0216	-.0144	-.0366	-.0144		
.8000				-.0176	-.0117	-.0144	-.0176	-.0013	-.0052	-.0032			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(b) Run 17 – No boundary layer trip – bad dew point for α = + 3 to 5 (cont'd)

α = 1

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0157	.0118	.0131	.0065	.0039	-.0032	-.0013	-.0059	-.0078	-.0085	-.0118	-.0124	
.2500	.0088	.0068	.0062	.0095	.0003	-.0042	-.0095	-.0167	-.0212	-.0232	-.0206	-.0167	T
.4000	-.0032	-.0019	-.0032	-.0026	-.0078	-.0144	-.0223	-.0298	-.0330	-.0376	-.0363	-.0311	O
.5000		.0376	.0212	.0121	-.0068	-.0167	-.0199	-.0285	-.0350	-.0409	-.0448	-.0435	P
.6500			.0593	.0475	.0285	.0108	-.0068	-.0153	-.0285	.0009	-.0396		
.8000				.0665	.0468	.0350	.0193	.0036	-.0114	-.0180			
.1000	.0361	.0288	.0210	.0144	.0118	.0091	.0131	.0026	-.0045	.0000	-.0052	-.0065	
.2500	.0324	.0298	.0258	.0226	.0206	.0062	-.0036	-.0068	-.0147	-.0108	-.0134	-.0088	B
.4000	.0308	.0288	.0249	.0275	.0157	.0078	-.0013	-.0134	-.0186	-.0258	-.0265	-.0232	T
.5000		.0901	.0763	.0488	.0212	.0317	.0016	-.0101	-.0206	-.0278	-.0317	-.0324	M
.6500			.1084	.0907	.0586	.0337	.0160	.0003	-.0095	-.0186	-.0232		
.8000				.1018	.0809	.0612	.0396	.0285	.0140	.0075			
.1000	.0203	.0170	.0078	.0078	.0078	.0124	.0144	.0085	.0032	.0085	.0065	.0059	D
.2500	.0235	.0229	.0196	.0131	.0203	.0106	.0058	.0098	.0065	.0124	.0072	.0078	I
.4000	.0341	.0308	.0282	.0301	.0236	.0223	.0210	.0163	.0144	.0117	.0098	.0078	F
.5000		.0524	.0530	.0366	.0281	.0484	.0216	.0183	.0144	.0131	.0131	.0111	F
.6500			.0491	.0632	.0301	.0229	.0229	.0157	.0190	-.0196	.0163		
.8000				.0353	.0340	.0262	.0203	.0849	.0255	.0255			

α = 2

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0013	-.0013	.0019	-.0006	-.0032	-.0013	-.0072	-.0117	-.0131	-.0150	-.0163	-.0163	
.2500	-.0163	-.0137	-.0104	.0026	-.0091	-.0124	-.0163	-.0235	-.0268	-.0294	-.0268	-.0229	T
.4000	-.0393	-.0353	-.0307	-.0275	-.0268	-.0307	-.0373	-.0422	-.0435	-.0475	-.0461	-.0402	O
.5000		.0065	-.0072	-.0163	-.0340	-.0386	-.0393	-.0442	-.0481	-.0514	-.0566	-.0540	P
.6500			.0337	.0265	.0095	-.0062	-.0232	-.0317	-.0442	.0003	-.0573		
.8000				.0435	.0258	.0160	.0022	-.0121	-.0252	-.0311			
.1000	.0458	.0393	.0360	.0235	.0203	.0157	.0131	.0091	.0019	.0058	.0013	.0000	
.2500	.0471	.0439	.0386	.0334	.0255	.0157	.0052	.0013	-.0072	-.0039	-.0065	-.0013	B
.4000	.0491	.0458	.0406	.0439	.0222	.0222	.0124	-.0016	-.0068	-.0147	-.0167	-.0140	T
.5000		.1304	.1068	.0760	.0425	.0327	.0190	.0042	-.0088	-.0160	-.0199	-.0212	M
.6500			.1418	.1169	.0796	.0527	.0344	.0173	.0068	-.0029	-.0095		
.8000				.1294	.1032	.0855	.0586	.0363	.0298	.0278			
.1000	.0445	.0406	.0340	.0242	.0235	.0170	.0203	.0209	.0150	.0209	.0176	.0163	D
.2500	.0635	.0576	.0491	.0307	.0347	.0281	.0216	.0249	.0196	.0255	.0203	.0216	I
.4000	.0884	.0812	.0714	.0714	.0491	.0530	.0498	.0406	.0366	.0327	.0294	.0262	F
.5000		.1238	.1140	.0923	.0766	.0714	.0583	.0484	.0393	.0353	.0366	.0327	F
.6500			.1081	.0904	.0701	.0589	.0576	.0491	.0511	-.0032	.0478		
.8000				.0858	.0773	.0694	.0563	.0484	.0550	.0589			

α = 3

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0137	-.0131	-.0091	-.0106	-.0078	-.0072	-.0117	-.0163	-.0163	-.0203	-.0216	-.0216	
.2500	-.0373	-.0340	-.0314	-.0065	-.0203	-.0196	-.0242	-.0301	-.0327	-.0347	-.0321	-.0294	T
.4000	-.0583	-.0563	-.0550	-.0550	-.0570	-.0615	-.0602	-.0547	-.0540	-.0573	-.0540	-.0507	O
.5000		-.0190	-.0301	-.0386	-.0570	-.0629	-.0629	-.0655	-.0661	-.0648	-.0648	-.0622	P
.6500			.0095	.0055	-.0075	-.0226	-.0317	-.0461	-.0579	.0003	-.0697		
.8000				.0822	.0072	-.0019	-.0137	-.0862	-.0386	-.0439			
.1000	.0556	.0498	.0452	.0321	.0275	.0235	.0209	.0170	.0091	.0117	.0072	.0065	
.2500	.0576	.0550	.0491	.0445	.0353	.0255	.0144	.0098	.0013	.0026	.0000	.0052	B
.4000	.0602	.0570	.0517	.0570	.0334	.0340	.0049	.0108	.0055	-.0036	-.0068	-.0042	T
.5000		.1638	.1343	.0996	.0622	.0327	.0340	.0183	.0039	-.0059	-.0085	-.0091	M
.6500			.1733	.1412	.0999	.0710	.0527	.0344	.0232	.0114	.0042		
.8000				.1359	.1306	.1054	.0753	.0452	.0504	.0425			
.1000	.0694	.0629	.0543	.0425	.0353	.0307	.0327	.0334	.0255	.0321	.0288	.0281	D
.2500	.0950	.0891	.0805	.0511	.0556	.0452	.0386	.0399	.0340	.0373	.0321	.0347	I
.4000	.1186	.1133	.1068	.1120	.0906	.0956	.0851	.0655	.0596	.0537	.0491	.0465	F
.5000		.1828	.1644	.1382	.1192	.0956	.0909	.0838	.0701	.0609	.0563	.0530	F
.6500			.1638	.1356	.1076	.0937	.0845	.0805	.0812	.0211	.0740		
.8000				.1356	.1231	.1076	.0891	.0714	.0891	.0664			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(b) Run 17 – No boundary layer trip – bad dew point for α = + 3 to 5 (concl'd)

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0281	-.0229	-.0209	-.0216	-.0111	-.0124	-.0163	-.0209	-.0203	-.0255	-.0268	-.0275	
.2500	-.0524	-.0511	-.0498	-.0176	-.0439	-.0288	-.0301	-.0360	-.0380	-.0393	-.0373	-.0340	T
.4000	-.0727	-.0727	-.0720	-.0720	-.0747	-.0766	-.0799	-.0779	-.0760	-.0747	-.0727	-.0681	O
.5000		-.0399	-.0491	-.0570	-.0733	-.0786	-.0805	-.0825	-.0838	-.0805	-.0792	-.0727	P
.6500			-.0111	-.0137	-.0242	-.0360	-.0511	-.0583	-.0681	.0013	-.0786		
.8000				.0019	-.0098	-.0183	-.0288	-.0399	-.0511	-.0556			
.1000	.0661	.0583	.0556	.0425	.0373	.0327	.0294	.0255	.0170	.0176	.0150	.0137	
.2500	.0661	.0648	.0602	.0550	.0452	.0360	.0242	.0190	.0098	.0098	.0072	.0131	B
.4000	.0661	.0629	.0609	.0668	.0452	.0458	.0386	.0235	.0183	.0078	.0045	.0058	T
.5000		.1933	.1585	.1218	.0819	.0334	.0491	.0321	.0163	.0085	.0032	.0013	M
.6500			.2051	.1644	.1205	.0904	.0714	.0517	.0393	.0262	.0176		
.8000				.1867	.1513	.1238	.0969	.0563	.0648	.0576			
.1000	.0943	.0812	.0766	.0642	.0484	.0452	.0458	.0465	.0373	.0432	.0419	.0412	D
.2500	.1186	.1159	.1100	.0727	.0891	.0648	.0543	.0550	.0478	.0491	.0465	.0471	I
.4000	.1389	.1356	.1330	.1389	.1199	.1225	.1186	.1015	.0943	.0825	.0773	.0740	F
.5000		.2332	.2077	.1788	.1553	.1120	.1297	.1146	.1002	.0891	.0825	.0740	F
.6500			.2162	.1782	.1448	.1264	.1225	.1100	.1074	.0249	.0963		
.8000				.1847	.1611	.1421	.1258	.0963	.1159	.1133			

$\alpha = 5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0488	-.0442	-.0389	-.0226	-.0167	-.0186	-.0226	-.0258	-.0252	-.0311	-.0330	-.0330	
.2500	-.0707	-.0707	-.0694	-.0203	-.0576	-.0478	-.0432	-.0452	-.0445	-.0452	-.0432	-.0399	T
.4000	-.0855	-.0855	-.0855	-.0855	-.0881	-.0894	-.0914	-.0897	-.0884	-.0878	-.0871	-.0851	O
.5000		-.0576	-.0655	-.0707	-.0858	-.0891	-.0891	-.0904	-.0897	-.0864	-.0838	-.0779	P
.6500			-.0294	-.0307	-.0393	-.0498	-.0622	-.0688	-.0786	.0013	-.0884		
.8000				-.0163	-.0255	-.0327	-.0425	-.0524	-.0622	-.0655			
.1000	.0769	.0665	.0638	.0553	.0475	.0422	.0383	.0337	.0252	.0245	.0226	.0226	
.2500	.0707	.0727	.0661	.0648	.0570	.0465	.0353	.0288	.0196	.0190	.0144	.0209	B
.4000	.0710	.0652	.0671	.0789	.0566	.0593	.0514	.0366	.0307	.0190	.0144	.0157	T
.5000		.2227	.1821	.1428	.1015	.0347	.0629	.0452	.0294	.0216	.0157	.0131	M
.6500			.2286	.1867	.1415	.1094	.0897	.0688	.0543	.0399	.0314		
.8000				.2103	.1723	.0832	.1172	.0648	.0805	.0733			
.1000	.1258	.1107	.1028	.0779	.0642	.0609	.0609	.0596	.0504	.0556	.0536	.0556	D
.2500	.1415	.1435	.1356	.0851	.1146	.0943	.0786	.0740	.0642	.0642	.0576	.0609	I
.4000	.1366	.1507	.1526	.1644	.1448	.1487	.1428	.1254	.1192	.1068	.1015	.1009	F
.5000		.2804	.2476	.2136	.1874	.1238	.1520	.1356	.1192	.1081	.0996	.0910	F
.6500			.2581	.2175	.1808	.1592	.1520	.1376	.1330	.0386	.1199		
.8000				.2267	.1978	.1159	.1598	.1172	.1428	.1408			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(c) Run 18 – Repeat of 17

$\alpha = 3$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0144	-.0131	-.0072	-.0085	-.0072	-.0078	-.0124	-.0164	-.0164	-.0203	-.0216	-.0223	
.2500	-.0426	-.0453	-.0354	.3092	-.0203	-.0229	-.0249	-.0308	-.0328	-.0348	-.0328	-.0302	T
.4000	-.0623	-.0604	-.0584	-.0577	-.0577	-.0577	-.0538	-.0534	-.0541	-.0560	-.0547	-.0495	O
.5000		-.0216	-.0302	-.0380	-.0571	-.0630	-.0630	-.0639	-.0639	-.0646	-.0652	-.0560	P
.6500			.0114	.0062	-.0068	-.0213	-.0370	-.0442	-.0567	.0154	-.0692		
.8000				.0206	.0075	-.0016	-.0134	-.0252	-.0377	-.0429			
.1000	.0591	.0525	.0466	.0334	.0282	.0229	.0197	.0164	.0091	.0124	.0078	.0072	
.2500	.0551	.0512	.0466	.0420	.0328	.0249	.0144	.0091	.0019	.0019	.0006	.0032	B
.4000	.0597	.0558	.0499	.0466	.0341	.0334	.0249	.0121	.0055	-.0036	-.0049	-.0036	T
.5000		.1621	.1333	.0991	.0617	.0321	.0341	.0186	.0042	-.0036	-.0081	-.0101	M
.6500			.1728	.1420	.1006	.0718	.0534	.0350	.0245	.0121	.0049		
.8000				.1564	.1288	.1072	.0770	.0449	.0495	.0449			
.1000	.0735	.0656	.0538	.0420	.0354	.0308	.0321	.0328	.0256	.0328	.0295	.0295	D
.2500	.0978	.0965	.0820	-.2672	.0531	.0479	.0394	.0400	.0348	.0367	.0334	.0334	I
.4000	.1221	.1162	.1083	.1044	.0919	.0912	.0788	.0655	.0596	.0524	.0498	.0459	F
.5000		.1838	.1635	.1372	.1188	.0952	.0971	.0826	.0682	.0610	.0570	.0459	F
.6500			.1613	.1357	.1075	.0931	.0905	.0793	.0813	-.0032	.0741		
.8000				.1357	.1213	.1088	.0905	.0701	.0872	.0879			

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0301	-.0262	-.0210	-.0196	-.0111	-.0131	-.0170	-.0210	-.0203	-.0255	-.0269	-.0275	
.2500	-.0557	-.0544	-.0531	.0433	-.0400	-.0308	-.0315	-.0367	-.0387	-.0400	-.0380	-.0354	T
.4000	-.0761	-.0754	-.0748	-.0748	-.0767	-.0761	-.0787	-.0760	-.0741	-.0728	-.0708	-.0662	O
.5000		-.0393	-.0492	-.0564	-.0735	-.0794	-.0807	-.0823	-.0623	-.0797	-.0790	-.0718	P
.6500			-.0091	-.0124	-.0236	-.0360	-.0498	-.0570	-.0675	.0078	-.0787		
.8000				.0009	-.0095	-.0173	-.0285	-.0396	-.0501	-.0547			
.1000	.0689	.0610	.0551	.0426	.0367	.0321	.0275	.0236	.0164	.0177	.0144	.0144	
.2500	.0636	.0623	.0564	.0525	.0439	.0347	.0242	.0177	.0098	.0091	.0078	.0105	B
.4000	.0656	.0623	.0590	.0571	.0452	.0452	.0380	.0236	.0177	.0072	.0045	.0059	T
.5000		.1916	.1581	.1207	.0813	.0328	.0485	.0318	.0167	.0088	.0029	.0016	M
.6500			.2026	.1653	.1206	.0911	.0715	.0524	.0393	.0262	.0177		
.8000				.1840	.1531	.1256	.0941	.0560	.0665	.0600			
.1000	.0991	.0872	.0761	.0623	.0479	.0452	.0446	.0446	.0367	.0433	.0413	.0420	D
.2500	.1194	.1168	.1096	.0091	.0840	.0656	.0557	.0544	.0485	.0492	.0459	.0459	I
.4000	.1417	.1378	.1338	.1319	.1220	.1214	.1168	.0997	.0918	.0800	.0754	.0721	F
.5000		.2310	.2073	.1772	.1548	.1122	.1292	.1141	.0990	.0885	.0819	.0734	F
.6500			.2118	.1777	.1443	.1272	.1213	.1095	.1069	.0183	.0964		
.8000				.1830	.1626	.1430	.1226	.0957	.1147	.1147			

$\alpha = 5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0485	-.0426	-.0380	-.0242	-.0177	-.0183	-.0223	-.0262	-.0249	-.0308	-.0321	-.0328	
.2500	-.0702	-.0702	-.0689	-.0019	-.0571	-.0498	-.0452	-.0459	-.0452	-.0459	-.0439	-.0400	T
.4000	-.0846	-.0846	-.0840	-.0840	-.0866	-.0872	-.0892	-.0885	-.0879	-.0865	-.0859	-.0839	O
.5000		-.0571	-.0643	-.0702	-.0846	-.0879	-.0886	-.0892	-.0885	-.0852	-.0833	-.0774	P
.6500			-.0275	-.0288	-.0380	-.0485	-.0610	-.0675	-.0774	.0085	-.0885		
.8000				-.0150	-.0242	-.0308	-.0406	-.0511	-.0610	-.0649			
.1000	.0800	.0682	.0649	.0571	.0485	.0420	.0354	.0334	.0249	.0242	.0216	.0229	
.2500	.0695	.0708	.0649	.0623	.0557	.0452	.0354	.0275	.0190	.0183	.0157	.0183	B
.4000	.0708	.0649	.0669	.0689	.0564	.0584	.0511	.0367	.0295	.0190	.0157	.0157	T
.5000		.2165	.1806	.1417	.0997	.0341	.0623	.0459	.0308	.0216	.0157	.0131	M
.6500			.2289	.1882	.1410	.1102	.0911	.0695	.0537	.0393	.0308		
.8000				.2112	.1758	.1456	.1180	.0669	.0833	.0774			
.1000	.1286	.1109	.1030	.0813	.0662	.0603	.0577	.0597	.0498	.0551	.0538	.0557	D
.2500	.1397	.1411	.1338	.0843	.1128	.0951	.0807	.0735	.0643	.0643	.0597	.0584	I
.4000	.1555	.1496	.1509	.1529	.1430	.1457	.1404	.1252	.1174	.1056	.1016	.0997	F
.5000		.2736	.2448	.2119	.1844	.1220	.1509	.1351	.1193	.1069	.0990	.0905	F
.6500			.2564	.2171	.1790	.1567	.1321	.1370	.1311	.0308	.1193		
.8000				.2263	.2000	.1764	.1587	.1180	.1443	.1423			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(c) Run 18 - Repeat of 17 (concl'd)

$\alpha = 6$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0488	-.0475	-.0488	-.0521	-.0259	-.0213	-.0265	-.0292	-.0272	-.0318	-.0144	-.0344	
.2500	-.0715	-.0728	-.0715	-.0374	-.0748	-.0741	-.0735	-.0735	-.0702	-.0669	-.0577	-.0452	T
.4000	-.0069	-.0676	-.0876	-.0876	-.0902	-.0922	-.0941	-.0938	-.0931	-.0918	-.0911	-.0098	O
.5000		-.0708	-.0767	-.0813	-.0912	-.0918	-.0905	-.0918	-.0898	-.0879	-.0872	-.0811	P
.6500			-.0419	-.0446	-.0511	-.0603	-.0715	-.0774	-.0846	.0032	-.0931		
.8000				-.0341	-.0387	-.0446	-.0531	-.0623	-.0708	-.0741			
.1000	.0863	.0823	.0725	.0672	.0646	.0515	.0436	.0423	.0324	.0324	.0265	.0318	
.2500	.0781	.0820	.0735	.0721	.0662	.0557	.0465	.0367	.0275	.0269	.0236	.0255	B
.4000	.0744	.0679	.0744	.0771	.0666	.0698	.0646	.0491	.0419	.0301	.0262	.0262	T
.5000		.2395	.2021	.1614	.1181	.0360	.0774	.0596	.0439	.0347	.0282	.0255	M
.6500			.2532	.2086	.1600	.1285	.1102	.0846	.0675	.0531	.0446		
.8000				.2361	.1948	.1705	.1357	.0754	.0997	.0964			
.1000	.1352	.1299	.1214	.1194	.0905	.0728	.0702	.0715	.0597	.0662	.0610	.0662	D
.2500	.1496	.1548	.1450	.1096	.1411	.1299	.1201	.1102	.0977	.0938	.0813	.0708	I
.4000	.1614	.1555	.1621	.1647	.1568	.1621	.1588	.1430	.1351	.1220	.1174	.1161	F
.5000		.3104	.2789	.2428	.2093	.1279	.1680	.1515	.1338	.1226	.1154	.1088	F
.6500			.2971	.2532	.2112	.1889	.1817	.1620	.1521	.0498	.1377		
.8000				.2702	.2335	.2151	.1889	.1377	.1705	.1705			

$\alpha = 7$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0564	-.0564	-.0577	-.0636	-.0544	-.0203	-.0275	-.0321	-.0315	-.0367	-.0374	-.0354	
.2500	-.0771	-.0790	-.0784	-.0548	-.0830	-.0849	-.0895	-.0941	-.0941	-.0915	-.0610	-.0574	T
.4000	-.0905	-.0918	-.0925	-.0925	-.0945	-.0964	-.0977	-.0977	-.0970	-.0964	-.0957	-.0944	O
.5000		-.0836	-.0876	-.0915	-.0941	-.0941	-.0935	-.0924	-.0911	-.0911	-.0905	-.0879	P
.6500			-.0577	-.0570	-.0623	-.0701	-.0793	-.0846	-.0905	.0032	-.0977		
.8000				-.0472	-.0518	-.0564	-.0629	-.0715	-.0793	-.0826			
.1000	.0991	.0938	.0879	.0787	.0761	.0610	.0531	.0505	.0413	.0406	.0341	.0380	
.2500	.0830	.0876	.0817	.0823	.0751	.0672	.0567	.0456	.0370	.0370	.0324	.0344	B
.4000	.0787	.0708	.0813	.0840	.0767	.0807	.0774	.0623	.0551	.0426	.0373	.0387	T
.5000		.2595	.2208	.1795	.1342	.0370	.0922	.0741	.0583	.0485	.0406	.0380	M
.6500			.4631	.2289	.1803	.1482	.1285	.1003	.0833	.0675	.0596		
.8000				.2364	.2256	.1902	.1528	.0865	.1187	.1134			
.1000	.1555	.1502	.1457	.1424	.1306	.0813	.0807	.0826	.0728	.0774	.0715	.0735	D
.2500	.1601	.1667	.1601	.1371	.1581	.1522	.1463	.1397	.1312	.1286	.1135	.0918	I
.4000	.1693	.1627	.1739	.1765	.1713	.1772	.1752	.1600	.1521	.1390	.1331	.1311	F
.5000		.3432	.3084	.2710	.2284	.1312	.1857	.1666	.1495	.1397	.1111	.1259	F
.6500			.5208	.2860	.2427	.2184	.2079	.1849	.1738	.0642	.1574		
.8000				.3017	.2774	.2466	.2158	.1580	.1981	.1961			

$\alpha = 9$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0698	-.0705	-.0725	-.0790	-.0948	-.0613	-.0351	-.0397	-.0416	-.0469	-.0475	-.0462	
.2500	-.0886	-.0899	-.0892	-.0662	-.0945	-.0984	-.1043	-.1115	-.1148	-.1174	-.1115	-.0997	T
.4000	-.1007	-.1014	-.1014	-.1020	-.1033	-.1053	-.1059	-.1062	-.1069	-.1069	-.1069	-.1023	O
.5000		-.1023	-.1050	-.1063	-.0997	-.0991	-.0971	-.0957	-.0970	-.0977	-.0983	-.0970	P
.6500			-.0819	-.0793	-.0826	-.0879	-.0944	-.0990	-.1063	.0045	-.1102		
.8000				-.0741	-.0754	-.0774	-.0819	-.0885	-.0944	-.0964			
.1000	.1125	.1164	.1132	.1007	.0889	.0830	.0731	.0712	.0626	.0626	.0514	.0561	
.2500	.0905	.1050	.1056	.1050	.0997	.0925	.0813	.0682	.0584	.0590	.0525	.0544	B
.4000	.0869	.0777	.0961	.0928	.0987	.1040	.1040	.0905	.0819	.0688	.0623	.0636	T
.5000		.2973	.2592	.2165	.1706	.0406	.1240	.1029	.0879	.0767	.0675	.0642	M
.6500			.0039	.2610	.2190	.1902	.1639	.1331	.1141	.0997	.0865		
.8000				.3096	.2617	.2269	.1908	.1088	.1534	.1456			
.1000	.1824	.1870	.1857	.1798	.1837	.1443	.1082	.1109	.1043	.1096	.1010	.1023	D
.2500	.1791	.1949	.1949	.1713	.1942	.1909	.1857	.1798	.1732	.1765	.1640	.1542	I
.4000	.1877	.1791	.1975	.1949	.2021	.2093	.2100	.1967	.1889	.1758	.1692	.1659	F
.5000		.3997	.3642	.3209	.2706	.1397	.2211	.1987	.1849	.1744	.1659	.1613	F
.6500			.0859	.3406	.3017	.2781	.2586	.2322	.2186	.0951	.1967		
.8000				.3837	.3371	.3043	.2728	.1974	.2479	.2420			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(d) Run 19 – With boundary layer trip (4)

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0127	-.0239	.0311	.0180	.0121	.0114	.0055	.0022	-.0016	-.0009	-.0042	-.0055	
.2500	.0327	.0327	.0163	.3174	.0118	.0052	-.0006	-.0078	-.0118	-.0157	-.0131	-.0098	T
.4000	.0311	.0278	.0318	.0672	.0101	.0036	-.0075	-.0160	-.0206	-.0252	-.0245	-.0206	O
.5000		.1298	.0557	.0229	.0170	.0065	.0065	-.0114	-.0219	-.0298	-.0337	-.0317	P
.6500			.1996	.0435	.0396	.0350	.0121	.0081	-.0088	.0062	-.0239		
.8000				.1399	.0049	.0324	.0219	.0173	.0042	-.0016			
.1000	.0311	.0469	.0147	.0075	.0068	.0049	.0029	-.0022	-.0068	-.0049	-.0095	-.0101	
.2500	.0177	.0275	-.0045	.0124	.0059	-.0026	-.0104	-.0137	-.0196	-.0157	-.0177	-.0157	B
.4000	.0127	.0081	.0022	-.0068	-.0049	-.0055	-.0154	-.0245	-.0278	-.0344	-.0337	-.0311	T
.5000		.0741	-.0170	.0216	-.0052	.0327	-.0111	-.0239	-.0337	-.0396	-.0422	-.0422	M
.6500			.1524	.0665	.0298	.0154	.0016	-.0147	-.0245	-.0331	-.0376		
.8000				.1589	.0304	.0390	.0232	.0206	-.0022	-.0049			
.1000	.0183	.0708	-.0163	-.0104	-.0052	-.0065	-.0026	-.0045	-.0052	-.0039	-.0052	-.0045	D
.2500	-.0150	-.0052	-.0209	-.3050	-.0059	-.0078	-.0098	-.0059	-.0078	.0000	-.0045	-.0059	I
.4000	-.0183	-.0196	-.0295	-.0741	-.0150	-.0091	-.0078	-.0085	-.0072	-.0091	-.0091	-.0104	F
.5000		-.0557	-.0728	-.0013	-.0223	.0262	-.0177	-.0124	-.0118	-.0098	-.0085	-.0104	F
.6500			-.0472	.0229	-.0098	-.0196	-.0104	-.0229	-.0157	-.0393	-.0137		
.8000				.0190	.0255	.0065	.0013	.0032	-.0065	-.0032			

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0095	-.0377	.0108	.0009	-.0009	-.0022	-.0055	-.0108	-.0114	-.0141	-.0154	-.0160	
.2500	-.0124	-.0085	-.0124	.0603	-.0091	-.0131	-.0163	-.0229	-.0249	-.0282	-.0262	-.0236	T
.4000	-.0252	-.0252	-.0193	-.0259	-.0232	-.0259	-.0331	-.0390	-.0422	-.0449	-.0422	-.0370	O
.5000		.0570	-.0098	-.0255	-.0347	-.0380	-.0341	-.0393	-.0465	-.0511	-.0550	-.0524	P
.6500			.1209	.0081	-.0049	-.0055	-.0206	-.0258	-.0396	.0049	-.0514		
.8000				.0740	-.0091	.0091	-.0045	-.0137	-.0268	-.0327			
.1000	.0514	.0639	.0350	.0232	.0213	.0173	.0134	.0101	.0029	.0068	.0022	.0009	
.2500	.0472	.0557	.0144	.0282	.0255	.0170	.0065	.0019	-.0052	-.0032	-.0045	-.0026	B
.4000	.0534	.0469	.0311	.0337	.0186	.0206	.0127	.0009	-.0049	-.0134	-.0134	-.0121	T
.5000		.1594	.0085	.0741	.0491	.0327	.0183	.0039	-.0078	-.0150	-.0190	-.0203	M
.6500			.2304	.0809	.0783	.0547	.0383	.0199	.0081	-.0285	-.0088		
.8000				.2019	.0662	.0780	.0609	.0380	.0295	.0275			
.1000	.0610	.1016	.0242	.0223	.0223	.0196	.0190	.0209	.0144	.0209	.0177	.0170	D
.2500	.0596	.0642	.0268	-.0321	.0347	.0301	.0229	.0249	.0196	.0249	.0216	.0209	I
.4000	.0787	.0721	.0505	.0596	.0419	.0465	.0459	.0399	.0373	.0314	.0288	.0249	F
.5000		.1023	.0183	.0997	.0839	.0708	.0524	.0432	.0386	.0360	.0360	.0321	F
.6500			.1094	.0727	.0832	.0603	.0590	.0458	.0478	-.0334	.0426		
.8000				.1278	.0753	.0688	.0655	.0517	.0563	.0603			

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0301	-.0531	-.0111	-.0137	-.0118	-.0137	-.0170	-.0209	-.0203	-.0255	-.0275	-.0282	
.7500	-.0613	-.0600	-.0560	.0049	-.0344	-.0318	-.0318	-.0370	-.0383	-.0403	-.0383	-.0357	T
.4000	-.0793	-.0800	-.0734	-.0721	-.0774	-.0734	-.0728	-.0711	-.0698	-.0691	-.0665	-.0632	O
.5000		-.0062	-.0541	-.0633	-.0731	-.0803	-.0797	-.0790	-.0783	-.0763	-.0750	-.0698	P
.6500			.0580	-.0140	-.0337	-.0383	-.0501	-.0540	-.0645	.0036	-.0763		
.8000				.0180	-.0390	-.0193	-.0304	-.0390	-.0475	-.0527			
.1000	.0701	.0774	.0511	.0400	.0367	.0334	.0288	.0242	.0177	.0190	.0150	.0144	
.2500	.0652	.0836	.0259	.0475	.0449	.0357	.0259	.0180	.0108	.0108	.0088	.0114	B
.4000	.0675	.0590	.0564	.0846	.0419	.0459	.0380	.0252	.0180	.0081	.0055	.0068	T
.5000		.2082	.0449	.1780	.0856	.0337	.0482	.0324	.0180	.0101	.0049	.0022	M
.6500			.2809	.1216	.1334	.0934	.0737	.0508	.0376	.0252	.0173		
.8000				.2291	.1458	.1380	.1045	.0613	.0685	.0632			
.1000	.1003	.1305	.0623	.0537	.0485	.0472	.0459	.0452	.0380	.0446	.0426	.0426	D
.2500	.1266	.1436	.0819	.0426	.0793	.0675	.0577	.0551	.0491	.0511	.0472	.0472	I
.4000	.1449	.1390	.1298	.1367	.1193	.1193	.1108	.0963	.0878	.0773	.0721	.0701	F
.5000		.2145	.0990	.2413	.1587	.1141	.1279	.1114	.0963	.0865	.0799	.0721	F
.6500			.2229	.1357	.1671	.1317	.1239	.1049	.1022	.0816	.0937		
.8000				.2111	.1848	.1573	.1350	.1003	.1160	.1160			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(d) Run 19 – With boundary layer trip (4) (concl'd)

$\alpha = 6$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0537	-.0682	-.0406	-.0367	-.0275	-.0262	-.0295	-.0314	-.0314	-.0354	-.0360	-.0282	
.2500	-.0715	-.0728	-.0688	-.0249	-.0734	-.0741	-.0734	-.0728	-.0688	-.0669	-.0590	-.0472	T
.4000	-.0839	-.0852	-.0800	-.0806	-.0859	-.0879	-.0892	-.0898	-.0891	-.0885	-.0871	-.0858	O
.5000		-.0367	-.0839	-.0852	-.0918	-.0931	-.0911	-.0894	-.0862	-.0855	-.0849	-.0809	P
.6500			.0118	-.0439	-.0524	-.0616	-.0708	-.0760	-.0832	.0032	-.0911		
.8000				-.0180	-.0658	-.0462	-.0540	-.0626	-.0698	-.0731			
.1000	.0872	.1036	.0642	.0629	.0629	.0524	.0446	.0432	.0327	.0327	.0268	.0321	
.2500	.0760	.0983	.0432	.0636	.0655	.0557	.0465	.0354	.0282	.0275	.0236	.0262	B
.4000	.0767	.0655	.0728	.1226	.0629	.0695	.0636	.0498	.0419	.0308	.0268	.0268	T
.5000		.2315	.0826	.2007	.1200	.0360	.0767	.0599	.0449	.0357	.0285	.0258	M
.6500			.3153	.2163	.1684	.1271	.1088	.0819	.0675	.0531	.0445		
.8000				.2756	.2101	.1793	.1452	.0803	.0973	.0940			
.1000	.1410	.1718	.1049	.0997	.0905	.0787	.0741	.0747	.0642	.0682	.0629	.0603	D
.2500	.1475	.1712	.1121	.0885	.1390	.1298	.1200	.1082	.0970	.0944	.0826	.0734	I
.4000	.1607	.1508	.1528	.2033	.1489	.1574	.1528	.1396	.1311	.1193	.1140	.1127	F
.5000		.2682	.1666	.2860	.2118	.1292	.1679	.1494	.1311	.1212	.1134	.1068	F
.6500			.3035	.2602	.2209	.1888	.1796	.1580	.1507	.0498	.1357		
.8000				.2937	.2760	.2255	.1993	.1429	.1671	.1671			

TABLE XIV (continued)

Flat Double Delta Wing Pressure Data

(e) Run 20 – No boundary layer trip - all gaps sealed

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0318	.0278	.0245	.0173	.0114	.0101	.0062	.0022	-.0016	-.0055	-.0081	-.0088	
.2500	.0334	.0275	.0223	.0236	.0124	.0065	.0006	-.0078	-.0026	-.0177	-.0157	-.0124	T
.4000	.0265	.0259	.0200	.0180	.0101	.0029	-.0055	-.0160	-.0206	-.0265	-.0258	-.0219	O
.5000		.0787	.0551	.0432	.0183	.0052	-.0006	-.0098	-.0190	-.0281	-.0327	-.0308	P
.6500			.0868	.0717	.0501	.0311	.0127	.0055	-.0095	-.0265	-.0226		
.8000				.0911	.0721	.0570	.0393	.0216	.0052	-.0013			
.1000	.0245	.0173	.0160	.0095	.0068	.0049	.0029	-.0022	-.0068	-.0101	-.0141	-.0141	
.2500	.0150	.0144	.0131	.0118	.0052	-.0013	-.0104	-.0131	-.0196	-.0183	-.0209	-.0203	B
.4000	.0049	.0029	.0042	.0029	-.0029	-.0062	-.0147	-.0239	-.0285	-.0344	-.0357	-.0331	T
.5000		.0518	.0393	.0209	-.0013	.0387	-.0137	-.0222	-.0321	-.0386	-.0413	-.0419	M
.6500			.0776	.0665	.0390	.0167	-.0003	-.0147	-.0245	-.0324	-.0376		
.8000				.0793	.0603	.0432	.0216	.0236	.0000	-.0039			
.1000	-.0072	-.0104	-.0085	-.0078	-.0045	-.0052	-.0032	-.0045	-.0052	-.0045	-.0059	-.0052	D
.2500	-.0183	-.0131	-.0091	-.0118	-.0072	-.0078	-.0111	-.0052	-.0170	-.0006	-.0052	-.0078	I
.4000	-.0216	-.0229	-.0157	-.0150	-.0131	-.0091	-.0091	-.0078	-.0078	-.0078	-.0098	-.0111	F
.5000		-.0268	-.0157	-.0223	-.0196	.0334	-.0131	-.0124	-.0131	-.0104	-.0085	-.0111	F
.6500			-.0091	-.0052	-.0111	-.0144	-.0131	-.0203	-.0150	-.0059	-.0150		
.8000				-.0118	-.0118	-.0137	-.0177	.0019	-.0052	-.0026			

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0052	.0019	.0052	.0013	-.0006	-.0019	-.0059	-.0104	-.0124	-.0177	-.0190	-.0196	
.2500	-.0150	-.0118	-.0085	.0072	-.0085	-.0118	-.0163	-.0229	-.0177	-.0308	-.0282	-.0262	T
.4000	-.0341	-.0295	-.0262	-.0236	-.0229	-.0268	-.0321	-.0380	-.0413	-.0452	-.0445	-.0399	O
.5000		.0104	-.0052	-.0150	-.0321	-.0373	-.0373	-.0419	-.0465	-.0511	-.0544	-.0524	P
.6500			.0386	.0301	.0131	-.0032	-.0190	-.0268	-.0380	-.0072	-.0485		
.8000				.0419	.0275	.0183	.0045	-.0091	-.0229	-.0288			
.1000	.0465	.0387	.0367	.0249	.0209	.0170	.0131	.0098	.0039	.0006	-.0032	-.0026	
.2500	.0472	.0446	.0387	.0347	.0249	.0177	.0065	.0019	-.0052	-.0052	-.0078	-.0065	B
.4000	.0485	.0452	.0393	.0347	.0236	.0203	.0111	.0000	-.0052	-.0144	-.0170	-.0157	T
.5000		.1298	.1043	.0754	.0432	.0387	.0190	.0045	-.0072	-.0150	-.0190	-.0209	M
.6500			.1389	.1147	.0786	.2714	.0347	.0177	.0078	-.0019	-.0078		
.8000				.1311	.1049	.0839	.0603	.0406	.0308	.0255			
.1000	.0413	.0367	.0314	.0236	.0216	.0190	.0190	.0203	.0163	.0183	.0157	.0170	D
.2500	.0623	.0564	.0472	.0275	.0334	.0295	.0229	.0249	.0124	.0255	.0203	.0196	I
.4000	.0826	.0747	.0655	.0583	.0465	.0472	.0432	.0380	.0360	.0308	.0275	.0242	F
.5000		.1193	.1095	.0905	.0754	.0760	.0564	.0465	.0393	.0360	.0354	.0314	F
.6500			.1003	.0845	.0655	.2747	.0537	.0445	.0458	.0052	.0406		
.8000				.0891	.0773	.0655	.0557	.0498	.0537	.0544			

$\alpha = 4$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0314	-.0282	-.0229	-.0209	-.0118	-.0131	-.0163	-.0203	-.0216	-.0275	-.0288	-.0301	
.2500	-.0544	-.0531	-.0518	-.0131	-.0400	-.0288	-.0295	-.0347	-.0308	-.0406	-.0393	-.0373	T
.4000	-.0747	-.0741	-.0734	-.0734	-.0754	-.0754	-.0774	-.0757	-.0737	-.0731	-.0704	-.0665	O
.5000		-.0373	-.0472	-.0544	-.0715	-.0780	-.0800	-.0809	-.0816	-.0790	-.0776	-.0717	P
.6500			-.0088	-.0108	-.0219	-.0344	-.0481	-.0560	-.0658	-.0009	-.0770		
.8000				.0022	-.0075	-.0154	-.0265	-.0376	-.0481	-.0527			
.1000	.0675	.0596	.0564	.0426	.0380	.0334	.0295	.0249	.0183	.0170	.0098	.0124	
.2500	.0655	.0642	.0583	.0557	.0459	.0373	.0268	.0190	.0118	.0104	.0072	.0078	B
.4000	.0669	.0623	.0603	.0590	.0459	.0465	.0387	.0252	.0186	.0081	.0055	.0062	T
.5000		.1941	.1541	.1233	.0833	.0393	.0491	.0331	.0186	.0101	.0049	.0022	M
.6500			.2022	.1629	.1222	.0921	.0737	.0540	.0403	.0265	.0186		
.8000				.1825	.1557	.1281	.0967	.0599	.0691	.0626			
.1000	.0990	.0879	.0793	.0636	.0498	.0465	.0459	.0452	.0400	.0446	.0387	.0426	D
.2500	.1200	.1174	.1102	.0688	.0859	.0662	.0564	.0537	.0426	.0511	.0465	.0452	I
.4000	.1416	.1364	.1338	.1325	.1213	.1220	.1161	.1009	.0924	.0812	.0760	.0727	F
.5000		.2315	.2013	.1777	.1348	.1174	.1292	.1140	.1003	.0891	.0826	.0740	F
.6500			.2111	.1737	.1442	.1265	.1219	.1101	.1062	.0275	.0957		
.8000				.1802	.1632	.1435	.1232	.0976	.1173	.1153			

TABLE XIV (concluded)

Flat Double Delta Wing Pressure Data

(e) Run 20 – No boundary layer trip - all gaps sealed (concl'd)

$\alpha^{\circ} = 6$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0551	-.0518	-.0524	-.0531	-.0255	-.0229	-.0268	-.0295	-.0301	-.0360	-.0373	-.0380	
.2500	-.0741	-.0754	-.0747	-.0419	-.0754	-.0728	-.0701	-.0688	-.0596	-.0642	-.0577	-.0491	T
.4000	-.0879	-.0879	-.0879	-.0879	-.0898	-.0911	-.0938	-.0927	-.0921	-.0914	-.0901	-.0888	O
.5000		-.0688	-.0754	-.0800	-.0905	-.0918	-.0911	-.0914	-.0901	-.0888	-.0875	-.0835	P
.6500			-.0429	-.0429	-.0501	-.0586	-.0691	-.0757	-.0829	.0009	-.0914		
.8000				-.0317	-.0370	-.0429	-.0508	-.0599	-.0691	-.0724			
.1000	.0872	.0826	.0721	.0662	.0636	-.0124	.0459	.0639	.0334	.0341	.0262	.0295	
.2500	.0774	.0819	.0741	.0741	.0675	.0577	.0472	.0373	.0282	.0282	.0249	.0255	B
.4000	.0760	.0682	.0760	.0780	.0675	.0708	.0655	.0514	.0435	.0317	.0278	.0278	T
.5000		.2387	.1981	.1620	.1193	.0400	.0787	.0613	.0455	.0357	.0291	.0265	M
.6500			.2547	.2101	.1616	.1301	.1124	.0862	.0691	.0540	.0455		
.8000				.2402	.1976	.1734	.1393	.0790	.1012	.0967			
.1000	.1423	.1344	.1246	.1193	.0892	.0104	.0728	.0734	.0636	.0701	.0636	.0675	D
.2500	.1515	.1574	.1489	.1161	.1630	.1305	.1174	.1062	.0879	.0924	.0826	.0747	I
.4000	.1639	.1561	.1639	.1659	.1574	.1620	.1594	.1442	.1357	.1232	.1180	.1167	F
.5000		.3076	.2735	.2420	.2099	.1318	.1698	.1527	.1357	.1245	.1167	.1101	F
.6500			.2976	.2530	.2117	.1888	.1816	.1619	.1521	.0531	.1370		
.8000				.2720	.2347	.2163	.1901	.1389	.1704	.1691			

TABLE XV

Warped Arrow Wing Pressure Data

(a) Bad Pressure Taps

y/b \ x/c	.010	.025	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	
.10	--	--	--	--	--	--	--	--	--	--	--	--	
.25	--	--	--	--	--	--	--	--	--	--	--	--	T
.40	--	--	--	--	--	--	--	--	xxxx	--	--	--	O
.55	--	--	xxxx	--	--	--	--	--	--	--	--	--	P
.70	--	--	xxxx	--	--	--	--	--	--	--	--	--	
.85				--	--	--	--	--	--	--			
.10	--	--	--	--	--	--	--	--	--	--	--	--	
.25	--	--	--	--	--	--	--	--	--	--	--	--	B
.40	--	--	--	--	--	--	--	--	--	--	--	--	T
.55	--	--	--	--	--	--	--	--	--	xxxx	--	xxxx	M
.70		--	--	--	--	--	--	--	--	--	--		
.85				--	--	--	--		--	xxxx			
.10	--	--	--	--	--	--	--	--	--	--	--	--	D
.25	--	--	--	--	--	--	--	--	--	--	--	--	I
.40	--	--	--	--	--	--	--	--	xxxx	xxxx	--		F
.55	--	--	xxxx	--	--	--	--	--	--	xxxx	--	xxxx	F
.70		--	xxxx	--	--	--	--	--	--	--	--		
.85				--	--	--	--	--	--	xxxx			

TABLE XV (continued)

Warped Arrow Wing Pressure Data

(b) Run 2 – No boundary layer trip

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0405	.0056	.0009	-.0148	-.0214	-.0293	-.0372	-.0438	-.0411	-.0398	-.0398	-.0359	
.2500	[illegible]	.0092	-.0131	-.0401	-.0546	-.0177	-.0520	-.0526	-.0487	-.0454	-.0395	-.0309	T
.4000	.0365	.0121	-.0062	-.0451	-.0747	-.0840	-.0754	-.0681	.0088	-.0550	-.0484	-.0339	O
.5500	.0480	.0362	.3878	-.0210	-.0052	-.0625	-.0730	-.1063	-.1004	-.0846	-.0740	-.0602	P
.7000		.0326	.0082	.0049	-.0405	-.0761	-.0965	-.1103	-.1143	-.0998	-.1017		
.8500				.0214	-.0069	-.0286	-.0523	-.0701	-.0859	-.0958			
.1000	.0563	.0444	.0444	.0438	.0477	.0477	.0517	.0471	.0405	.0319	.0181	.0108	
.2500	.0520	.0460	.0467	.0500	.0507	.0480	.0454	.0441	.0316	.0204	.0118	.0039	B
.4000	.0451	.0490	.0490	.0477	.0497	.0484	.0471	.0345	.0280	.0174	.0056	-.0016	T
.5500	.0507	.0513	.0513	.0513	.0513	.0513	.0381	.0306	.0233	.2327	.0102	.2505	M
.7000		.0398	.0438	.0418	.0457	.0411	.0385	.0352	.0240	.0095	-.0003		
.8500				.0102	.0115	.0095	.0121	.0121	-.0055	-.0062			
.1000	.0158	.0388	.0434	.0586	.0691	.0770	.0889	.0909	.0817	.0718	.0579	.0467	
.2500	.0164	.0368	.0599	.0902	.1053	.0658	.0974	.0968	.0803	.0658	.0513	.0349	D
.4000	.0085	.0368	.0553	.0929	.1245	.1324	.1225	.1027	.0191	.0724	.0540	.0322	I
.5500	.0026	.0151	-.3364	.0724	.0566	.1139	.1112	.1369	.1237	.3173	.0842	.3108	F
.7000		.0072	.0355	.0368	.0863	.1172	.1150	.1456	.1383	.1093	.1014		F
.8500				-.0111	.0184	.0381	.0645	.0823	.0803	.0895			

$\alpha = .5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0308	.0045	-.0039	-.0203	-.0256	-.0328	-.0413	-.0473	-.0453	-.0433	-.0440	-.0407	
.2500	.0269	.0000	-.0249	-.0486	-.0610	-.0558	-.0564	-.0558	-.0525	-.0492	-.0440	-.0354	T
.4000	.0269	.0019	-.0170	-.0558	-.0854	-.0919	-.0834	-.0743	-.0776	-.0605	-.0532	-.0388	O
.5500	.0387	.0269	-.0039	-.0302	-.0801	-.1037	-.1129	-.1095	-.1049	-.0951	-.0879	-.0767	P
.7000		.0217	.0157	-.0059	-.0513	-.0861	-.1039	-.1170	-.1118	-.1065	-.1045		
.8500				.0118	-.0170	-.0380	-.0610	-.0793	-.0944	-.0964			
.1000	.0591	.0499	.0492	.0473	.0499	.0512	.0538	.0492	.0427	.0348	.0190	.0118	
.2500	.0551	.0499	.0505	.0512	.0525	.0499	.0479	.0473	.0341	.0229	.0137	.0052	B
.4000	.0492	.0532	.0525	.0492	.0518	.0505	.0492	.0368	.0302	.0197	.0072	.0000	T
.5500	.0578	.0578	.0578	.0545	.0545	.0545	.0394	.0334	.0255	.0203	.0124	.0019	M
.7000		.0466	.0532	.0486	.0486	.0440	.0407	.0342	.0263	.0026	.0019		
.8500				.0183	.0209	.0249	.0216	.0177	.0052	-.0026			
.1000	.0282	.0453	.0532	.0676	.0755	.0840	.0952	.0965	.0880	.0701	.0630	.0525	
.2500	.0282	.0499	.0755	.0998	.1136	.1057	.1044	.1031	.0867	.0722	.0578	.0407	D
.4000	.0223	.0512	.0696	.1051	.1373	.1425	.1327	.1111	.1078	.0802	.0605	.0388	I
.5500	.0190	.0308	.0617	.0847	.1346	.1583	.1524	.1430	.1305	.1154	.1003	.0787	F
.7000		.0249	.0374	.0545	.0999	.1302	.1446	.1512	.1381	.1091	.1065		F
.8500				.0065	.0380	.0629	.0826	.0971	.0997	.0938			

$\alpha = 1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0252	.0003	-.0134	-.0233	-.0279	[illegible]	-.0436	-.0489	-.0476	-.0450	-.0463	-.0423	
.2500	.0103	-.0091	-.0341	-.0558	-.0650	-.0597	-.0591	-.0584	-.0551	-.0525	-.0473	-.0387	T
.4000	.0174	-.0062	-.0259	-.0633	-.0936	-.0975	-.0909	-.0780	-.0898	-.0649	-.0570	-.0419	O
.5500	.0295	.0170	-.0177	-.0287	-.0080	-.1097	-.1136	-.1088	-.1068	-.1016	-.0990	-.0918	P
.7000		.0124	-.0078	-.0150	-.0590	-.0912	-.1108	-.1148	-.1076	-.1043	-.1023		
.8500				.0026	-.0255	-.0472	-.0688	-.0872	-.0996	-.0891			
.1000	.0653	.0541	.0574	.0528	.0535	.0574	.0568	.0528	.0476	.0384	.0220	.0154	
.2500	.0597	.0538	.0545	.0538	.0571	.0532	.0512	.0505	.0381	.0269	.0170	.0085	B
.4000	.0541	.0587	.0568	.0535	.0555	.0541	.0528	.0400	.0334	.0229	.0106	.0032	T
.5500	.0630	.0624	.0624	.0000	.0578	.0578	.0427	.0367	.0288	.0236	.0157	.0039	M
.7000		.0531	.0603	.0538	.0524	.0479	.0446	.0374	.0295	.0019	.0052		
.8500				.0295	.0334	.0321	.0268	.0209	.0091	.0006			
.1000	.0400	.0538	.0709	.0762	.0814	.0932	.1005	.1018	.0952	.0834	.0683	.0578	D
.2500	.0413	.0630	.0886	.1097	.1221	.1129	.1103	.1090	.0932	.0794	.0643	.0473	I
.4000	.0367	.0650	.0827	.1169	.1491	.1517	.1438	.1181	.1233	.0879	.0675	.0452	F
.5500	.0335	.0453	.0801	.0387	.1458	.1675	.1563	.1455	.1357	.1252	.1147	.0957	F
.7000		.0406	.0682	.0688	.1115	.1391	.1555	.1522	.1371	.1062	.1076		
.8500				.0268	.0590	.0793	.0957	.1082	.1088	.0898			

TABLE XV (continued)

Warped Arrow Wing Pressure Data

(b) Run 2 - No boundary layer trip (cont'd)

$\alpha = -5$

	y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000
TOP	.1000	.0852	.0681	.0444	.0266	.0088	-.0029	-.0088	-.0161	-.0148	-.0108	-.0121	-.0088
	.2500	.0681	.0687	.0542	.0299	-.0003	-.0167	-.0167	-.0227	-.0207	-.0148	-.0088	.0023
	.4000	.0595	.0562	.0608	.0371	.0042	-.0213	-.0273	-.0329	-.0507	-.0243	-.0125	.0046
	.5500	.0523	.0628	.1233	.0549	.0121	-.0167	-.0338	-.0420	-.0460	-.0394	-.0282	-.0026
	.7000		.0605	.0230	.0730	.0381	.0026	-.0190	-.0368	-.0493	-.0572	-.0454	
	.8500				.0624	.0598	.0506	.0295	.0138	-.0065	-.0118		
BTM	.1000	-.0187	-.0180	-.0029	.0062	.0121	.0180	.0180	.0174	.0095	.0095	-.0062	-.0174
	.2500	-.0391	-.0319	-.0332	-.0187	.0161	.0194	.0161	.0102	.0003	-.0069	-.0141	-.0227
	.4000	-.0292	-.0273	-.0299	-.0332	-.0365	.0102	.0213	.0065	-.0006	-.0111	-.0230	-.0276
	.5500	-.0227	-.0227	-.0233	-.0259	-.0292	-.0417	-.0536	-.0368	-.0144	.0506	-.0118	.0480
	.7000		-.0316	-.0322	-.0362	-.0401	-.0441	-.0480	-.0526	-.0592	.0026	-.0724	
	.8500				-.0572	-.0565	-.0605	-.0637	-.0684	-.0730	-.0749		
DIFF	.1000	-.1039	-.0862	-.0473	-.0204	.0032	.0210	.0269	.0335	.0243	.0204	.0059	-.0085
	.2500	-.1072	-.1006	-.0875	-.0487	.0164	.0361	.0329	.0329	.0210	.0078	-.0052	-.0250
	.4000	-.0888	-.0835	-.0908	-.0704	-.0408	.0315	.0487	.0395	.0500	.0131	-.0105	-.0322
	.5500	-.0750	-.0855	-.1467	-.0809	-.0414	-.0250	-.0197	.0052	.0315	.0901	.0164	.0506
	.7000		-.0921	-.0553	-.1093	-.0783	-.0467	-.0289	-.0158	-.0098	.0599	-.0269	
	.8500				-.1197	-.1164	-.1111	-.0933	-.0822	-.0664	-.0631		

$\alpha = -2$

	y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000
TOP	.1000	.0612	.0355	.0335	.0000	-.0118	-.0190	-.0282	-.0342	-.0329	-.0296	-.0296	-.0256
	.2500	.0578	.0394	.0157	-.0118	-.0315	-.0388	-.0407	-.0427	-.0394	-.0355	-.0289	-.0184
	.4000	.0565	.0394	.0263	-.0078	-.0414	-.0585	-.0572	-.0566	-.0447	-.0441	-.0349	-.0190
	.5500	.0624	.0578	.0493	.0131	-.0361	-.0631	-.0782	-.0822	-.0789	-.0651	-.0519	-.0289
	.7000		.0533	.0539	.0375	-.0065	-.0447	-.0678	-.0829	-.0928	-.0994	-.0968	
	.8500				.0440	.0236	.0039	-.0190	-.0401	-.0532	-.0677		
BTM	.1000	.0309	.0223	.0256	.0263	.0309	.0315	.0361	.0335	.0250	.0204	.0078	-.0032
	.2500	.0197	.0151	.0203	.0315	.0342	.0355	.0328	.0295	.0171	.0078	.0006	-.0078
	.4000	.0098	.0131	.0138	.0223	.0381	.0355	.0329	.0204	.0144	.0039	-.0072	-.0131
	.5500	.0177	.0190	.0184	.0144	.0230	.0361	.0269	.0177	.0111	.0177	-.0032	.0065
	.7000		.0105	.0111	.0065	.0039	-.0026	.0000	.0065	.0085	.0032	-.0111	
	.8500				-.0190	-.0197	-.0243	-.0269	-.0315	-.0394	-.0427		
DIFF	.1000	-.0302	-.0131	-.0078	.0263	.0427	.0506	.0644	.0677	.0579	.0500	.0375	.0223
	.2500	-.0381	-.0243	.0046	.0434	.0657	.0743	.0736	.0723	.0565	.0434	.0295	.0105
	.4000	-.0467	-.0261	-.0125	.0302	.0796	.0941	.0901	.0770	.0592	.0480	.0276	.0059
	.5500	-.0447	-.0188	-.0309	.0013	.0591	.0993	.1052	.0999	.0901	.0828	.0486	.0355
	.7000		-.0428	-.0428	-.0309	.0105	.0421	.0678	.0895	.1014	.1027	.0836	
	.8500				-.0631	-.0434	-.0282	-.0078	.0085	.0138	.0249		

$\alpha = -1$

	y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000
TOP	.1000	.0499	.0230	.0124	-.0072	-.0184	-.0249	-.0341	-.0400	-.0374	-.0361	-.0368	-.0322
	.2500	.0486	.0249	.0011	-.0263	-.0420	-.0466	-.0473	-.0486	-.0447	-.0414	-.0355	-.0256
	.4000	.0479	.0269	.0098	-.0276	-.0578	-.0709	-.0670	-.0637	-.0644	-.0499	-.0420	-.0276
	.5500	.0578	.0493	.0217	-.0046	-.0539	-.0795	-.0933	-.0965	-.0932	-.0729	-.0591	-.0394
	.7000		.0446	.0302	.0210	-.0236	-.0617	-.0828	-.0979	-.1058	-.1078	-.1032	
	.8500				.0341	.0078	-.0124	-.0354	-.0558	-.0065	-.0821		
BTM	.1000	.0453	.0322	.0361	.0341	.0387	.0374	.0433	.0400	.0315	.0249	.0124	.0026
	.2500	.0381	.0309	.0335	.0381	.0414	.0414	.0394	.0355	.0236	.0131	.0052	-.0026
	.4000	.0262	.0302	.0322	.0374	.0433	.0414	.0394	.0262	.0203	.0098	-.0019	-.0078
	.5500	.0302	.0315	.0328	.0355	.0427	.0434	.0309	.0236	.0164	.0131	.0026	-.0026
	.7000		.0223	.0243	.0190	.0243	.0282	.0295	.0243	.0164	.0019	-.0065	
	.8500				-.0059	-.0059	-.0118	-.0164	-.0197	-.0275	-.0262		
DIFF	.1000	-.0046	.0092	.0236	.0414	.0571	.0624	.0775	.0801	.0690	.0611	.0493	.0348
	.2500	-.0105	.0059	.0322	.0644	.0835	.0881	.0868	.0841	.0684	.0545	.0407	.0230
	.4000	-.0216	.0032	.0223	.0650	.1012	.1124	.1064	.0900	.0947	.0598	.0400	.0197
	.5500	-.0276	-.0177	.0111	.0401	.0964	.1229	.1243	.1202	.1097	.0850	.0617	.0367
	.7000		-.0223	-.0059	-.0019	.0479	.0900	.1124	.1222	.1222	.1097	.0966	
	.8500				-.0400	-.0137	.0006	.0190	.0361	-.0210	.0558		

TABLE XV (continued)

Warped Arrow Wing Pressure Data

(b) Run 2 – No boundary layer trip (concl'd)

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0100	-.0114	-.0239	-.0298	-.0331	-.0417	-.0482	-.0541	-.0522	-.0495	-.0495	-.0476	
.2500	-.0013	-.0302	-.0505	-.0716	-.0729	-.0683	-.0656	-.0637	-.0604	-.0578	-.0518	-.0446	T
.4000	-.0029	-.0259	-.0456	-.0011	-.1054	-.1041	-.1021	-.0970	-.0957	-.0780	-.0655	-.0452	O
.5500	.0072	-.0065	-.0154	-.0578	-.1018	-.1136	-.1083	-.1081	-.1074	-.1087	-.1107	-.1081	P
.7000		-.0098	-.0209	-.0341	-.0747	-.1036	-.1134	-.1075	-.1049	-.1029	-.1009		
.8500				-.0170	-.0439	-.0642	-.0845	-.1002	-.0950	-.0858			
.1000	.0745	.0640	.0653	.0620	.0620	.0666	.0647	.0620	.0561	.0469	.0285	.0213	
.2500	.0676	.0630	.0604	.0624	.0624	.0597	.0584	.0578	.0459	.0341	.0236	.0151	B
.4000	.0528	.0653	.0627	.0614	.0614	.0607	.0601	.0478	.0419	.0308	.0183	.0098	T
.5500	.0584	.0597	.0696	.0656	.0354	.0650	.0692	.0432	.0353	.0301	.0222	.0098	M
.7000		.0485	.0727	.0622	.0603	.0550	.0524	.0445	.0360	.0019	.0131		
.8500				.0465	.0478	.0612	.0347	.0301	.0163	.0078			
.1000	.0637	.0775	.0893	.0919	.0952	.1083	.1129	.1162	.1083	.0965	.0781	.0689	D
.2500	.0669	.0932	.1110	.1340	.1353	.1281	.1241	.1215	.1064	.0919	.0755	.0597	I
.4000	.0558	.0913	.1083	.1425	.1668	.1648	.1622	.1449	.1377	.1088	.0839	.0550	F
.5500	.0512	.0643	.1051	.1235	.1373	.1786	.1576	.1513	.1428	.1389	.1330	.1179	F
.7000		.0583	.0937	.0964	.1350	.1586	.1659	.1521	.1409	.1049	.1141		
.8500				.0635	.0917	.1055	.1192	.1304	.1114	.0937			

$\alpha = 5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0397	-.0515	-.0456	-.0548	-.0548	-.0587	-.0640	-.0673	-.0640	-.0601	-.0587	-.0594	
.2500	-.0643	-.0847	-.0913	-.0867	-.0939	-.1031	-.1105	-.1005	-.0768	-.0678	-.0617	-.0558	T
.4000	-.0627	-.0870	-.1008	-.1060	-.1060	-.1093	-.1113	-.1160	-.1002	-.1271	-.1225	-.1009	O
.5500	-.0689	-.0801	-.0722	-.1044	-.1143	-.1143	-.1143	-.1150	-.1163	-.1176	-.1196	-.1215	P
.7000		-.0930	-.0360	-.0924	-.1140	-.1173	-.1153	-.1146	-.1133	-.1127	-.1114		
.8500				-.1006	-.1012	-.1091	-.1163	-.1091	-.1065	-.1012			
.1000	.0962	.0923	.0890	.0942	.0949	.0903	.0909	.0909	.0837	.0719	.0548	.0456	
.2500	.0696	.0867	.0880	.0834	.0860	.0847	.0847	.0821	.0729	.0597	.0486	.0387	B
.4000	.0351	.0850	.0811	.0831	.0831	.0863	.0844	.0720	.0661	.0557	.0432	.0340	T
.5500	.0124	.0525	.0893	.0880	.0880	.0880	.0735	.0671	.0580	.0514	.0462	.0298	M
.7000		-.0078	.0804	.0806	.0838	.0786	.0747	.0655	.0602	.0013	.0340		
.8500				.0645	.1137	.0658	.0612	.0573	.0389	.0311			
.1000	.1359	.1438	.1346	.1491	.1497	.1491	.1550	.1583	.1478	.1320	.1136	.1051	D
.2500	.1340	.1714	.1793	.1701	.1800	.1878	.1951	.1826	.1497	.1267	.1103	.0946	I
.4000	.0973	.1721	.1819	.1892	.1892	.1957	.1957	.1880	.1664	.1828	.1658	.1350	F
.5500	.0814	.1127	.1616	.1924	.2023	.2023	.1878	.1821	.1743	.1690	.1659	.1513	F
.7000		.0852	.1245	.1730	.1979	.1959	.1900	.1802	.1736	.1140	.1454		
.8500				.1651	.2149	.1749	.1776	.1664	.1454	.1323			

TABLE XV (continued)

Warped Arrow Wing Pressure Data

(c) Run 3 – With boundary layer trip (3)

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0620	.0652	.0396	.0036	-.0101	-.0173	-.0272	-.0331	-.0311	-.0285	-.0305	-.0246	
.2500	.0580	.0475	-.0147	-.0088	-.0305	-.0383	-.0403	-.0416	-.0383	-.0344	-.0278	-.0180	T
.4000	.0587	.0337	.0462	-.0101	-.0396	-.0561	-.0561	-.0563	.0334	-.0439	-.0353	-.0196	O
.5500	.0639	.0606	.0344	.0095	-.0357	-.0620	-.0764	-.0809	-.0756	-.0645	-.0448	-.0317	P
.7000		.0524	.0334	.0360	-.0104	-.0452	-.0681	-.0832	-.0924	-.0969	-.0845		
.8500				.0527	-.0134	.0036	-.0173	-.0383	-.0534	-.0684			
.1000	.0318	.0187	.0213	.0278	.0324	.0344	.0383	.0351	.0265	.0219	.0083	-.0016	
.2500	.0206	.0180	.0082	.0252	.0364	.0364	.0357	.0298	.0180	.0088	.0016	-.0068	B
.4000	.0160	.0147	.0101	.0730	.0390	.0377	.0337	.0209	.0144	.0039	-.0065	-.0124	T
.5500	.0160	.0187	.0206	.0252	.0219	.0403	.0272	.0173	.0108	.0337	-.0036	.0337	M
.7000		.0098	.0078	.0091	.0098	-.0019	.0013	.0058	.0104	.0334	-.0111		
.8500				-.0193	-.0232	-.0226	-.0357	-.0324	-.0396	-.0422			
.1000	-.0301	-.0465	-.0183	.0242	.0426	.0518	.0656	.0682	.0577	.0505	.0393	.0229	D
.2500	-.0374	-.0295	.0229	.0341	.0669	.0748	.0761	.0715	.0564	.0433	.0295	.0111	I
.4000	-.0426	-.0190	-.0360	.0839	.0787	.0938	.0898	.0773	-.0190	.0478	.0288	.0072	F
.5500	-.0479	-.0419	-.0137	.0157	.0577	.1023	.1036	.0983	.0865	.0983	.0412	.0655	F
.7000		-.0426	-.0255	-.0268	.0203	.0432	.0694	.0891	.1028	.1304	.0734		
.8500				-.0720	-.0098	-.0262	-.0183	.0058	.0137	.0262			

$\alpha = -1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0524	.0557	.0374	-.0052	-.0177	-.0236	-.0328	-.0387	-.0360	-.0347	-.0367	-.0308	
.2500	.0495	.0324	-.0278	-.0226	-.0410	-.0456	-.0462	-.0475	-.0436	-.0403	-.0344	-.0246	T
.4000	.0511	.0223	.0183	-.0288	-.0295	-.0688	-.0656	-.0629	.0347	-.0498	-.0419	-.0275	O
.5500	.0593	.0534	.0344	-.0003	-.0541	-.0784	-.0908	-.0917	-.0858	-.0747	-.0635	-.0453	P
.7000		.0439	.0340	.0203	-.0262	-.0609	-.0825	-.0963	-.1009	-.0924	-.0084		
.8500				.0465	-.0229	-.0045	-.0353	-.0524	-.0714	-.0825			
.1000	.0452	.0321	.0295	.0360	.0387	.0393	.0446	.0413	.0328	.0255	.0131	.0039	
.2500	.0403	.0331	.0127	.0331	.0436	.0423	.0410	.0370	.0246	.0469	.0062	-.0016	B
.4000	.0334	.0367	.0275	.0000	.0439	.0426	.0400	.0275	.0209	.0106	-.0006	-.0072	T
.5500	.0285	.0311	.0351	.0469	.0462	.0449	.0311	.0242	.0170	.0340	.0032	.0340	M
.7000		.0216	.0222	.0196	.0498	.0268	.0301	.0249	.0176	.0347	-.0052		
.8500				-.0052	-.0104	-.0091	-.0203	-.0190	-.0268	-.0255			
.1000	-.0072	-.0236	-.0078	.0413	.0564	.0629	.0774	.0800	.0688	.0603	.0498	.0347	D
.2500	-.0091	.0006	.0406	.0557	.0846	.0879	.0872	.0846	.0682	.0872	.0406	.0229	I
.4000	-.0177	.0144	.0091	.1009	.0734	.1115	.1056	.0904	-.0137	.0602	.0412	.0203	F
.5500	-.0308	-.0223	.0006	.0472	.1003	.1233	.1220	.1160	.1028	.1087	.0666	.0799	F
.7000		-.0222	-.0117	-.0006	.0760	.0878	.1127	.1212	.1186	.1271	.0832		
.8500				-.0517	.0124	-.0045	.0150	.0334	.0445	.0570			

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0429	.0423	.0036	-.0127	-.0206	-.0285	-.0370	-.0429	-.0410	-.0390	-.0403	-.0357	
.2500	.0383	.0239	-.0383	-.0351	-.0501	-.0501	-.0521	-.0521	-.0488	-.0456	-.0403	-.0311	T
.4000	.0410	.0101	-.0134	-.0442	-.1053	-.0823	-.0738	-.0688	.0360	-.0550	-.0484	-.0347	O
.5500	.0482	.0403	.0357	-.0160	-.0698	-.0935	-.1046	-.1068	-.0956	-.0838	-.0773	-.1061	P
.7000		.0314	.0353	.0006	-.0386	-.1074	-.0963	-.1087	-.1133	-.1055	-.0989		
.8500				.0334	-.0327	-.0203	-.0426	-.0694	-.0858	-.0969			
.1000	.0561	.0351	.0508	.0449	.0482	.0488	.0534	.0482	.0416	.0324	.0180	.0114	
.2500	.0521	.0438	.0511	.0423	.0515	.0495	.0475	.0442	.0318	.0206	.0114	.0042	B
.4000	.0515	.0520	.0436	.0915	.0508	.0501	.0154	.0347	.0281	.0176	.0058	-.0013	T
.5500	.0501	.0508	.0547	.0680	.0547	.0521	.0377	.0308	.0235	.0353	.0098	.0351	M
.7000		.0393	.0445	.0530	.0720	.0432	.0360	.0327	.0242	.0360	.0006		
.8500				.0098	.0052	.0163	.0052	.0131	.0072	-.0065			
.1000	.0131	-.0072	.0472	.0577	.0688	.0774	.0905	.0912	.0826	.0715	.0583	.0472	D
.2500	.0137	.0249	.0635	.0774	.1017	.0997	.0997	.0964	.0807	.0662	.0518	.0354	I
.4000	.0104	.0426	.0570	.1358	.1561	.1325	.0892	.1035	-.0078	.0727	.0543	.0334	F
.5500	.0019	.0104	.0190	.0761	.1246	.1456	.1423	.1356	.1192	.1192	.0871	.1415	F
.7000		.0078	.0091	.0524	.1107	.1507	.1343	.1415	.1376	.1415	.0996		
.8500				-.0235	.0380	.0367	.0478	.0825	.0891	.0904			

TABLE XV (concluded)

Warped Arrow Wing Pressure Data

(c) Run 3 – With boundary layer trip (3) (concl'd)

α = 1

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0301	.0328	-.0085	-.0209	-.0262	-.0347	-.0426	-.0485	-.0465	-.0439	-.0452	-.0414	
.2500	.0239	.0101	-.0593	-.0515	-.0613	-.0587	-.0574	-.0567	-.0534	-.0515	-.0462	-.0377	T
.4000	.0223	-.0012	-.0085	-.0636	-.0892	-.0944	-.0892	-.0773	.0360	-.0622	-.0550	-.0406	O
.5500	.0305	.0219	.0364	-.0324	-.0869	-.1065	-.1105	-.1071	-.1019	-.0986	-.0966	-.0894	P
.7000		.0137	.0360	-.0222	-.0517	-.0904	-.1060	-.1120	-.1042	-.1009	-.0969		
.8500				.0173	-.0514	-.0403	-.0612	-.0842	-.0979	-.0894			
.1000	.0669	.0498	.0570	.0544	.0551	.0590	.0583	.0544	.0492	.0387	.0229	.0164	
.2500	.0633	.0574	.0639	.0488	.0593	.0554	.0521	.0501	.0383	.0278	.0180	.0095	B
.4000	.0590	.0682	.0505	.0977	.0551	.0551	.0538	.0406	.0347	.0235	.0117	.0039	T
.5500	.0626	.0613	.0646	.0679	.0613	.0517	.0436	.0370	.0291	.0363	.0160	.0357	M
.7000		.0537	.0622	.0668	.0766	.0517	.0452	.0386	.0301	.0360	.0065		
.8500				.0304	.0317	.0330	.0068	.0813	.0108	.0009			
.1000	.0367	.0170	.0656	.0754	.0813	.0938	.1010	.1030	.0958	.0826	.0682	.0577	D
.2500	.0393	.0472	.1233	.1003	.1207	.1141	.1095	.1069	.0913	.0793	.0643	.0472	I
.4000	.0367	.0715	.0590	.1614	.1443	.1496	.1430	.1179	-.0013	.0858	.0668	.0445	F
.5500	.0321	.0393	.0282	.1003	.1482	.1673	.1542	.1441	.1310	.1350	.1127	.1251	F
.7000		.0399	.0262	.0891	.1284	.1422	.1520	.1507	.1343	.1369	.1035		
.8500				.0131	.0832	.0734	.0681	.1055	.1087	.0904			

α = 2

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0170	.0196	-.0229	-.0282	-.0314	-.0406	-.0150	-.0538	-.0511	-.0665	-.0492	-.0459	
.2500	.0065	-.0085	-.0767	-.0608	-.0682	-.0649	-.0643	-.0636	-.0610	-.0583	-.0524	-.0446	T
.4000	.0019	-.0164	-.0608	-.0026	-.1030	-.1003	-.0997	-.0963	.0373	-.0773	-.0648	-.0452	O
.5500	.0098	.0006	.0177	-.0570	-.0977	-.1102	-.1056	-.1045	-.1032	-.1065	-.1084	-.1078	P
.7000		-.0072	.0373	-.0504	-.0701	-.1002	-.1107	-.1048	-.1015	-.1002	-.0983		
.8500				-.0009	-.0704	-.0606	-.0789	-.0979	-.0940	-.0842			
.1000	.0741	.0643	.0675	.0636	.0636	.0660	.0669	.0636	.0577	.0685	.0301	.0223	
.2500	.0695	.0643	.0374	.0564	.0643	.0610	.0597	.0570	.0465	.0347	.0242	.0157	B
.4000	.0551	.0754	.0603	.1056	.0616	.0629	.0603	.0478	.0419	.0314	.0196	.0104	T
.5500	.0583	.0590	.0728	.0767	.0675	.0662	.0498	.0442	.0363	.0370	.0232	.0370	M
.7000		.0491	.0760	.0727	.0832	.0583	.0524	.0445	.0367	.0373	.0131		
.8500				.0488	.0462	.0429	.0147	.0298	.0180	.0080			
.1000	.0570	.0446	.0905	.0918	.0951	.1095	.0820	.1174	.1089	.0971	.0793	.0682	D
.2500	.0629	.0728	.1141	.1253	.1325	.1259	.1240	.1207	.1076	.0931	.0767	.0603	I
.4000	.0531	.0918	.1292	.1883	.1646	.1633	.1601	.1441	.0845	.1087	.0845	.0557	F
.5500	.0485	.0583	.0551	.1338	.1653	.1765	.1555	.1487	.1395	.1435	.1317	.1448	F
.7000		.0563	.0386	.1232	.1533	.1506	.1631	.1494	.1382	.1376	.1114		
.8500				.0498	.1166	.1035	.0937	.1278	.1120	.0930			

α = 5

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0341	-.0269	-.0524	-.0544	-.0538	[illegible]	-.0636	-.0662	-.0623	-.0590	-.0583	-.0583	
.2500	-.0623	-.0656	-.0990	-.0853	-.0885	-.0951	-.1036	-.1010	-.0859	-.0695	-.0597	-.0538	T
.4000	-.0603	-.0767	-.0984	-.1049	-.1036	-.1069	-.1102	-.1143	.0603	-.1241	-.1228	-.1025	O
.5500	-.0669	-.0761	.0600	-.1003	-.1126	-.1128	-.1128	-.1127	-.1107	-.1160	-.1186	-.1199	P
.7000		-.0829	.0396	-.0907	-.1117	-.1143	-.1117	-.1130	-.1117	-.1110	-.1091		
.8500				-.0845	-.1061	-.1068	-.1153	-.1107	-.1061	-.1009			
.1000	.0977	.0918	.0977	.0944	.0958	.0931	.0944	.0918	.0846	.0728	.0557	.0465	
.2500	.0668	.0666	.0649	.0761	.0879	.0853	.0853	.0807	.0728	.0590	.0485	.0387	B
.4000	.0393	.0925	.0813	.1266	.0846	.0872	.0646	.0710	.0671	.0560	.0442	.0350	T
.5500	.0157	.0511	.0938	.1003	.0905	.0872	.0721	.0688	.0589	.0606	.0471	.0399	M
.7000		-.0042	.0920	.0920	.1202	.0809	.0743	.0658	.0606	.0403	.0150		
.8500				.0642	.0727	.0720	.0393	.0576	.0406	.0314			
.1000	.1315	.1187	.1502	.1489	.1496	.1535	.1581	.1581	.1469	.1314	.1141	.1069	D
.2500	.1312	.1522	.1640	.1614	.1765	.1806	.1389	.1817	.1537	.1266	.1082	.0925	I
.4000	.0997	.1692	.1797	.2316	.1803	.1962	.1968	.1874	[illegible]	.1302	.1671	.1176	F
.5500	.0826	.1272	.0558	.2007	.2034	.2001	.1850	.1815	.1697	.1566	.1658	.1599	F
.7000		.0786	.0524	.1828	.2320	.1953	.1380	.1789	.1723	.1511	.1441		
.8500				.1487	.1709	.1789	.1546	.1684	.1468	[illegible]			

TABLE XVI

Warped Double Delta Wing Pressure Data

(a) Bad Pressure Taps

y/b \ x/c	.010	.025	.050	.100	.200	.300	.400	.500	.600	.700	.800	.900	
.10	--	--	--	--	--	xxxx	--	--	--	--	--	--	
.25	--	--	--	--	--	xxxx	--	--	--	--	--	--	T
.40	--	--	--	--	--	--	--	--	--	--	--	--	O
.50		--	--	--	--	--	--	--	--	--	--	--	P
.65			--	--	--	--	--	--	--	--	--		
.80				--	--	--	--	--	--	--			
.10	--	--	--	--	--	--	--	--	--	--	--	--	
.25	--	--	--	--	--	--	--	--	--	--	--	--	B
.40	--	--	--	--	--	--	--	--	xxxx	--	--	--	T
.50		--	--	--	--		--	--	--	--	--	--	M
.65			xxxx	--	--	--	--	--	--	--	--		
.80				--	--	--	xxxx	--	--	--			
.10	--	--	--	--	--	xxxx	--	--	--	--	--	--	D
.25	--	--	--	--	--	xxxx	--	--	--	--	--	--	I
.40	--	--	--	--	--	--	--	--	xxxx	--	--	--	F
.50		--	xxxx	--	--	--	--	--	--	--	--	--	F
.65				--	--	--	--	--	--	--	--		
.70				--	--	--	xxxx	--	--	--			

TABLE XVI (continued)

Warped Double Delta Wing Pressure Data

(b) Run 6 – No boundary layer trip

$\alpha = -5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0697	.0617	.0640	.022[illegible]	.0092	-.0052	.0019	-.0012	.0040	-.0019	-.0090	-.009[illegible]	TOP
.2500	.0663	.0650	.0699	.0567	.0131	-.0019	-.0045	-.0078	-.0124	-.0124	-.0111	-.0105	
.4000	.0660	.0677	.0605	.0647	.0269	.0203	.0019	-.0078	-.0137	-.0170	-.0157	-.0131	
.5000		.0551	.1110	.0761	.0355	.0157	.0013	-.0065	-.0144	-.0196	-.0153	-.0144	
.6500			.1162	.0821	.0559	.0400	.0302	.0203	.0093	.0026	.0026		
.8000				.0912	.0733	.0735	.0617	.0512	.0451	.0400			
.1000	-.0322	-.0230	-.0111	.0026	.0078	.0072	.0072	.0019	-.0039	-.0052	-.0105	-.0093	BTM
.2500	-.0335	-.0302	-.0309	-.0229	.0065	.0039	-.0032	-.0118	-.0273	-.0177	-.0065	-.0170	
.4000	-.0256	-.0647	-.0651	-.0660	-.0460	-.0627	-.0607	-.0400	-.0446	-.0453	-.0692	-.0660	
.5000		.0012	-.0039	-.0216	-.0129	-.0348	-.0341	-.0367	-.0466	-.0692	-.0525	-.0519	
.6500			.1107	.0663	.0354	.0111	-.0065	-.0275	-.0627	-.0571	-.0663		
.8000				.0933	.0577	.0341	.0106	-.0092	-.0256	-.0387			
.1000	-.1019	-.0568	-.0552	-.0197	-.0013	.0124	.0052	.0052	-.0035	-.0032	-.0006	.0000	DIFF
.2500	-.1013	-.0952	-.0808	-.0597	-.0085	.0078	.0013	-.0039	-.0098	-.0052	.0045	-.0065	
.4000	-.0716	-.1124	-.1058	-.0907	-.0730	-.0631	-.0647	-.0321	-.0308	-.0282	-.0135	-.0130	
.5000		-.0551	-.1119	-.0945	-.0661	-.0506	-.0356	-.0302	-.0302	-.0235	-.0231	-.0354	
.6500			.0144	-.0157	-.0201	-.0289	-.0337	-.0479	-.0525	-.0597	-.0689		
.8000				-.0098	-.0256	-.0393	-.0308	-.0610	-.0709	-.0787			

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0456	.0266	.0114	-.0029	-.0114	-.0213	-.0180	-.0226	-.0128	-.0226	-.0298	-.0235	TOP
.2500	.0522	.0266	.0062	-.0128	-.0213	-.0160	-.0305	-.0319	-.0346	-.0325	-.0318	-.0312	
.4000	.0495	.0255	.0134	-.0060	-.0200	-.0305	-.0397	-.0653	-.0485	-.0492	-.0659	-.0613	
.5000		.0151	.0366	.0095	-.0233	-.0344	-.0630	-.0669	-.0508	-.0548	-.0528	-.0695	
.6500			.0308	.0137	-.0019	-.0137	-.0225	-.0203	-.0361	-.0600	-.0613		
.8000				.0180	.0147	.0006	.0009	-.0069	-.0062	-.010[illegible]			
.1000	.0200	.01[illegible]7	.0220	.0266	.0259	.0275	.0246	.0191	.0121	.0101	.0069	.0055	BTM
.2500	.0200	.0279	.0255	.0305	.0331	.0272	.0180	.0062	-.0062	-.0009	.0029	.0009	
.4000	.0495	.0095	.0117	.0200	.0206	.0193	.0141	.0052	-.0073	-.0124	-.0120	-.0111	
.5000		.0909	[illegible]	.0594	.0682	.0[illegible]97	.0272	.0141	-.0009	-.0103	-.0200	-.0233	
.6500			.0663	.1165	.0965	.0662	.0666	.0256	.0078	-.0085	-.0177		
.8000				.1533	.1145	.0650	.0456	.0318	.0154	-.0009			
.1000	-.0256	-.0078	.0105	.0295	.0373	.0499	.0427	.0420	.0249	.0325	.0363	.0331	DIFF
.2500	-.0021	.0013	.0243	.0633	.0544	.0633	.0486	.0400	.0302	.0315	.0348	.0321	
.4000	.0000	-.0190	.0039	.0269	.0407	.0499	.0538	.0505	.0407	.0367	.0288	.0295	
.5000		.0558	.0659	.0499	.0716	.0742	.0702	.0610	.0498	.0439	.0328	.0262	
.6500			.0[illegible]5	.1227	.0984	.0720	.0669	.0544	.0439	.0315	.02[illegible]		
.8000				.1152	.0997	.0761	.0446	.0387	.0236	.0099			

$\alpha = -1$

y/b \ x/c	.0100	.025	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	[illegible]	.0157	.0000	-.0136	-.0164	-.0262	-.024[illegible]	-.0269	-.0133	-.0282	-.0354	-.0341	TOP
.2500	[illegible]	.0067	-.0156	-.0305	-.0358	-.0226	-.0384	-.0390	-.0406	-.0377	-.0377	-.0371	
.4000	.0321	.0019	-.0124	-.0302	-.0413	-.0499	-.0571	-.0606	-.0617	-.0606	-.0558	-.0505	
.5000		.0103	.0032	-.0160	-.0430	-.0522	-.0587	-.0623	-.0669	-.0676	-.0656	[illegible]	
.6500			.0065	-.0072	-.0203	-.0302	-.0370	-.0446	-.0512	-.0551	-.0564		
.8000				-.0039	-.0045	-.0091	-.0164	-.0223	-.0256	-.0275			
.1000	.0335	.0295	.0302	.0363	.0335	.0361	.0302	.0262	.0183	.0144	.0105	.0111	BTM
.2500	.0364	.0423	.0423	.0417	.0410	.0351	.0252	.0147	.0022	.0069	.0095	.0075	
.4000	.055[illegible]	.0302	[illegible]	.0366	.0315	.0305	.0282	.0170	.0032	-.0013	-.0072	-.0026	
.5000		.12[illegible]	.1116	.0916	.0732	.0594	.0643	.0280	.0131	.0006	-.0035	-.0113	
.6500			.1057	.1621	.1196	.0899	.0663	.0426	.0236	.0065	-.0065		
.8000				.1766	.1352	.1063	.1155	.0505	.0308	.0131			
.1000	-.0319	.0137	.0302	.0366	.0499	.0623	.0545	.0512	.0367	.0427	.0459	.0453	DIFF
.2500	.0000	.0353	.0578	.0722	.0766	.0578	.0637	.0538	.0427	.0427	.0473	.0446	
.4000	.0246	.0272	.0496	.0650	.0729	.0608	.0654	.0776	.0649	.0590	.0455	.0479	
.5000		.11[illegible]	.1066	.1077	.1162	.1116	.1031	.0912	.0781	.0682	.0571	.0505	
.6500			.1011	.1700	.1191	.1201	.1063	.0871	.0748	.0617	.0519		
.8000				.1805	.1398	.1135	.1319	.0728	.0564	.0407			

TABLE XVI (continued)

Warped Double Delta Wing Pressure Data

(b) Run 6 — No boundary layer trip (cont'd)

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0243	.0026	-.0118	-.0190	-.0203	-.0315	-.0368	-.0335	-.0249	-.0335	-.0407	-.0394	
.2500	.0164	-.0164	-.0388	-.0499	-.0519	-.0039	-.0473	-.0453	-.0473	-.0447	-.0440	-.0440	T
.4000	.0072	-.0282	-.0420	-.0565	-.0657	-.0703	-.0756	-.0762	-.0742	-.0709	-.0644	-.0585	O
.5000		-.0039	-.0151	-.0368	-.0618	-.0565	-.0749	-.0788	-.0801	-.0808	-.0788	-.0748	P
.6500			-.0177	-.0276	-.0368	-.0446	-.0512	-.0571	-.0644	-.0683	-.0690		
.8000				-.0249	-.0223	-.0256	-.0315	-.0367	-.0394	-.0413			
.1000	.0499	.0434	.0394	.0420	.0427	.0394	.0355	.0315	.0243	.0197	.0157	.0177	
.2500	.0480	.0513	.0506	.0473	.0447	.0401	.0315	.0217	.0072	.0105	.0013	.0138	B
.4000	.0453	.0447	.0480	.0447	.0388	.0427	.0401	.0289	.0144	.0092	.0032	.0078	T
.5000		.1545	.1446	.1170	.0947	.0776	.0591	.0420	.0256	.0131	.0026	-.0013	M
.6500			-.0006	.1866	.1413	.1097	.0854	.0578	.0387	.0203	.0072		
.8000				.2003	.1550	.1215	.0026	.0609	.0473	.0295			
.1000	.0256	.0407	.0513	.0611	.0631	.0710	.0723	.0651	.0493	.0532	.0565	.0572	D
.2500	.0315	.0677	.0894	.0973	.0966	.0440	.0789	.0670	.0545	.0552	.0453	.0570	I
.4000	.0181	.0730	.0901	.1012	.1045	.1131	.1157	.1051	.0887	.0801	.0677	.0663	F
.5000		.1585	.1598	.1539	.1565	.1341	.1341	.1208	.1057	.0939	.0814	.0735	F
.6500			.0170	.2142	.1781	.1544	.1367	.1150	.1032	.0887	.0762		
.8000				.2253	.1773	.1471	.0341	.1057	.0867	.0709			

$\alpha = 1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0124	-.0105	-.0223	-.0282	-.0275	-.0354	-.0347	-.0380	-.0302	-.0387	-.0459	-.0439	
.2500	-.0039	-.0387	-.0643	-.0689	-.0623	-.0308	-.0544	-.0518	-.0518	-.0498	-.0505	-.0492	T
.4000	-.0223	-.0577	-.0709	-.0827	-.0892	-.0932	-.0932	-.0892	-.0839	-.0780	-.0708	-.0643	O
.5000		-.0361	-.0367	-.0551	-.0774	-.0860	-.0906	-.0931	-.0944	-.0958	-.0938	-.0892	P
.6500			-.0380	-.0452	-.0524	-.0583	-.0636	-.0688	-.0754	-.0780	-.0793		
.8000				-.0439	-.0400	-.0419	-.0459	-.0511	-.0538	-.0551			
.1000	.0617	.0538	.0492	.0512	.0516	.0466	.0446	.0407	.0321	.0269	.0210	.0256	
.2500	.0590	.0610	.0604	.0564	.0538	.0485	.0407	.0302	.0157	.0183	.0196	.0210	B
.4000	.0256	.0544	.0564	.0531	.0479	.0558	.0544	.0426	.0262	.0216	.0157	.0203	T
.5000		.1858	.1746	.1444	.1162	.0971	.0761	.0690	.0406	.0269	.0157	.0137	M
.6500			.1305	.2125	.1633	.1305	.1036	.0761	.0557	.0334	.0209		
.8000				.2224	.1751	.1417	.1568	.0846	.0616	.0413			
.1000	.0492	.0643	.0715	.0794	.0794	.0820	.0794	.0787	.0623	.0656	.0669	.0695	D
.2500	.0630	.0997	.1247	.1254	.1162	.0794	.0952	.0820	.0676	.0682	.0702	.0702	I
.4000	.0479	.1122	.1273	.1359	.1372	.1490	.1477	.1318	.1102	.0997	.0866	.0046	F
.5000		.2219	.2114	.1995	.1936	.1831	.1667	.1522	.1351	.1227	.1095	.1030	F
.6500			.1686	.2578	.2158	.1089	.1673	.1450	.1312	.1115	.1003		
.8000				.2664	.2152	.1837	.2027	.1358	.1154	.0964			

$\alpha = 2a$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0022	-.0259	-.0344	-.0351	-.0436	-.0397	-.0377	-.0423	-.0344	-.0430	-.0495	-.0482	
.2500	-.0302	-.0919	-.0794	-.0741	-.0774	-.0361	-.0649	-.0604	-.0610	-.0564	-.0584	-.0577	T
.4000	-.0528	-.0817	-.0935	-.1027	-.1034	-.1020	-.1020	-.0977	-.0905	-.0846	-.0800	-.0754	O
.5000		-.0643	-.0551	-.0709	-.0899	-.0958	-.1017	-.1043	-.1056	-.1062	-.1036	-.0984	P
.6500			-.0570	-.0610	-.0662	-.0708	-.0754	-.0800	-.0046	-.0866	-.0879		
.8000				-.0610	-.0557	-.0564	-.0597	-.0629	-.0656	-.0669			
.1000	.0692	.0640	.0600	.0574	.0587	.0561	.0521	.0489	.0403	.0351	.0272	.0318	
.2500	.0649	.0689	.0682	.0643	.0610	.0564	.0485	.0380	.0229	.0249	.0262	.0282	B
.4000	.0022	.0600	.0633	.0613	.0561	.0659	.0646	.0557	.0380	.0328	.0255	.0308	T
.5000		.2114	.1995	.1661	.1359	.1162	.0912	.0754	.0551	.0400	.0269	.0262	M
.6500			.1692	.2342	.1837	.1496	.1207	.0931	.0708	.0479	.0134		
.8000				.2427	.1942	.1607	.1797	.1017	.0780	.0564			
.1000	.0715	.0899	.0945	.0925	.1024	.0958	.0899	.0912	.0748	.0781	.0768	.0801	D
.2500	.0952	.1608	.1477	.1385	.1385	.0925	.1135	.0984	.0840	.0833	.0846	.0860	I
.4000	.0551	.1418	.1369	.1641	.1595	.1680	.1687	.1535	.1286	.1174	.1056	.1062	F
.5000		.2757	.2547	.2370	.2258	.2120	.1930	.1797	.1732	.1607	.1463	.1305	.1246	F
.6500			.2263	.2952	.2500	.2204	.1961	.1732	.1555	.1345	.1213		
.8000				.3038	.2500	.2171	.2395	.1646	.1437	.1233			

TABLE XVI (continued)

Warped Double Delta Wing Pressure Data

(b) Run 6 – No boundary layer trip (concl'd)

α = 2b

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0032	-.0269	-.0347	-.0361	-.0439	-.0393	-.0380	-.0420	-.0341	-.0426	-.0499	-.0679	
.2500	-.0276	-.0620	-.0803	-.0764	-.0734	-.0357	-.0646	-.0606	-.0600	-.0530	-.0580	-.0574	T
.4000	-.0525	-.0807	-.0925	-.1017	-.1024	-.1011	-.1004	-.0964	-.0892	-.0833	-.0793	-.0748	O
.5000		-.0705	-.0541	-.0698	-.0889	-.0948	-.1007	-.1036	-.1069	-.1055	-.1029	-.0970	P
.6500			-.0557	-.0603	-.0656	-.0702	-.0748	-.0787	-.0846	-.0866	-.0879		
.8000				-.0603	-.0544	-.0550	-.0583	-.0616	-.0642	-.0655			
.1000	.0695	.0636	.0617	.0577	.0590	.0551	.0498	.0472	.0393	.0328	.0262	.0115	
.2500	.0639	.0672	.0666	.0620	.0606	.0541	.0475	.0377	.0219	.0246	.0255	.0278	B
.4000	.0019	.0590	.0623	.0597	.0544	.0649	.0663	.0544	.0374	.0321	.0255	.0308	T
.5000		.2089	.1978	.1381	.1368	.1145	.0902	.0734	.0550	.0606	.0251	.0262	M
.6500			.0626	.2122	.1824	.1496	.1200	.0905	.0695	.0672	.0334		
.8000				.2426	.1941	.1606	.1849	.1036	.0736	.0570			
.1000	.0728	.0906	.0965	.0938	.1030	.0945	.0879	.0892	.0735	.0755	.0761	.0794	D
.2500	.0915	.1292	.1469	.1384	.1391	.0898	.1122	.0984	.0820	.0826	.0866	.0852	I
.4000	.0544	.1398	.1549	.1615	.1569	.1661	.1667	.1509	.1266	.1154	.1049	.1056	F
.5000		.2795	.2519	.2080	.2237	.2093	.1909	.1770	.1600	.1462	.1311	.1232	F
.6500			.0984	.2926	.2480	.2198	.1948	.1692	.1542	.1538	.1213		
.8000				.3029	.2485	.2157	.2432	.1652	.1429	.1226			

α = 5

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0505	-.0610	-.0584	-.0662	-.0866	-.0524	-.0485	-.0544	-.0485	-.0564	-.0610	-.0597	
.2500	-.0811	-.1043	-.0977	-.0977	-.0997	-.0465	-.1089	-.1102	-.1194	-.1122	-.0905	-.0705	T
.4000	-.1141	-.1102	-.1082	-.1076	-.1102	-.1115	-.1108	-.1098	-.1091	-.1091	-.1098	-.1098	O
.5000		-.0918	-.0958	-.1036	-.1135	-.1108	-.1115	-.1108	-.1095	-.1075	-.1062	-.1049	P
.6500			-.1006	-.0973	-.0980	-.1000	-.1026	-.1045	-.1072	-.1075	-.1085		
.8000				-.0996	-.0944	-.0918	-.0924	-.0937	-.0944	-.0950			
.1000	.0912	.0931	.0918	.0912	.0879	.0820	.0813	.0734	.0656	.0597	.0513	.0551	
.2500	.0695	.0813	.0872	.0866	.0833	.0787	.0748	.0636	.0465	.0492	.0479	.0515	B
.4000	-.0511	.0734	.0795	.0807	.0737	.0951	.1049	.0934	.0750	.0685	.0600	.0659	T
.5000		.2716	.2598	.2237	.1896	.1653	.1384	.1193	.0996	.0826	.0715	.0662	M
.6500			.1608	.2947	.2403	.2036	.1708	.1386	.1164	.0862	.0691		
.8000				.2996	.2518	.2177	.2334	.1501	.1213	.0977			
.1000	.1417	.1542	.1502	.1574	.1745	.1345	.1299	.1279	.1141	.1161	.1123	.1148	D
.2500	.1509	.1856	.1850	.1843	.1830	.1253	.1837	.1738	.1660	.1614	.1384	.1227	I
.4000	.0623	.1837	.1876	.1883	.1839	.2066	.2158	.2032	.1842	.1777	.1698	.1757	F
.5000		.3635	.3556	.3274	.3031	.2762	.2500	.2301	.2091	.1901	.1777	.1711	F
.6500			.2695	.3921	.3383	.3036	.2734	.2432	.2236	.1967	.1777		
.8000				.3993	.3462	.3095	.3259	.2439	.2157	.1928			

TABLE XVI (continued)

Warped Double Delta Wing Pressure Data

(c) Run 7 - With boundary layer trip (3)

$\alpha = -5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0714	[illegible]	.0557	[illegible]	[illegible]	[illegible]	[illegible]	-.0019	[illegible]	[illegible]	-.0031	[illegible]	
.2500	[illegible]	[illegible]	[illegible]	[illegible]	.0157	-.0091	[illegible]	-.0072	-.0117	-.0111	[illegible]	[illegible]	T
[illegible]	.0665	.0675	.0642	.0209	.0301	.0229	.0052	-.0062	-.0121	-.0167	[illegible]	-.0121	O
.5000		.0691	.1730	.0511	[illegible]	.0176	.0026	-.0059	[illegible]	-.0163	-.0177	[illegible]	P
.6500			.1255	.1216	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]				[illegible]	[illegible]	[illegible]	.0557	[illegible]	[illegible]	[illegible]			
.1000	[illegible]	-.0150	-.0209	[illegible]	.0098	[illegible]	[illegible]	[illegible]	[illegible]	-.0039	-.0091	-.0091	
.2500	[illegible]	[illegible]	-.0321	.0091	.0058	.0065	-.0026	-.0111	-.0216	-.0170	[illegible]	[illegible]	B
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T
.5000		.0052	.0013	-.0360	-.0353	-.0360	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	M
.6500			.0571	[illegible]	.0265	[illegible]	-.0062	-.0265	[illegible]	[illegible]	-.0619		
[illegible]				.1226	[illegible]	.0170	.0570	-.0104	[illegible]	[illegible]			
.1000	[illegible]	[illegible]	-.0766	-.0157	-.0006	[illegible]	.0052	[illegible]	-.0091	[illegible]	.0000	-.0006	D
[illegible]	[illegible]	-.0956	[illegible]	[illegible]	-.0098	[illegible]	[illegible]	[illegible]	-.0098	[illegible]	.0117	-.0065	I
[illegible]	-.0714	-.1120	-.1087	-.0661	-.0747	[illegible]	-.0445	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F
[illegible]		[illegible]	-.1717	[illegible]	-.0747	[illegible]	[illegible]	-.0295	[illegible]	[illegible]	[illegible]	[illegible]	F
[illegible]			[illegible]	-.0229	-.0272	-.0150	[illegible]	-.0511	-.0524	-.0590	-.0675		
[illegible]				[illegible]	-.0747	-.0609	.0013	-.0577	-.0695	[illegible]			

$\alpha = -2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	[illegible]	.0311	.0219	[illegible]	-.0101	-.0199	[illegible]	-.0213	[illegible]	-.0219	[illegible]	[illegible]	
.2500	.0517	.0249	.0150	[illegible]	-.0190	[illegible]	-.0308	-.0321	[illegible]	-.0314	[illegible]	[illegible]	T
[illegible]	.0507	[illegible]	.0206	-.0311	[illegible]	-.0265	-.0370	-.0429	-.0475	[illegible]	[illegible]	[illegible]	O
.5000		[illegible]	[illegible]	[illegible]	-.0262	-.0327	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P
.6500			.0331	[illegible]	.0042	-.0127	[illegible]	[illegible]	-.0311	-.0409	-.0609		
[illegible]				.0216	.0491	.0124	-.0026	-.0052	[illegible]	[illegible]			
.1000	[illegible]	[illegible]	[illegible]	.0271	[illegible]	[illegible]	.0257	[illegible]	.0127	[illegible]	[illegible]	[illegible]	
.2500	[illegible]	[illegible]	[illegible]	.0550	[illegible]	.0275	[illegible]	[illegible]	[illegible]	[illegible]	.0052	.0019	B
[illegible]	.0501	.0121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0065	-.0075	[illegible]	-.0167	[illegible]	T
.5000		[illegible]	[illegible]	.0255	[illegible]	[illegible]	[illegible]	[illegible]	-.0026	-.0111	-.0203	[illegible]	M
.6500			[illegible]	.1695	[illegible]	[illegible]	[illegible]	.0245	.0075	[illegible]	[illegible]		
[illegible]				[illegible]	.1003	[illegible]	[illegible]	[illegible]	.0190	.0019			
.1000	[illegible]	[illegible]	-.0170	[illegible]	[illegible]	[illegible]	[illegible]	.0419	[illegible]	[illegible]	[illegible]	[illegible]	D
.2500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	I
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0524	[illegible]	.0400	[illegible]	.0295	.0301	F
.5000		.0511	.0072	.0268	.0701	[illegible]	[illegible]	.0583	.0472	[illegible]	[illegible]	[illegible]	F
.6500			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]				[illegible]	.0511	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

$\alpha = -1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.0255	-.0242	-.0275	-.0176	-.0275	[illegible]	[illegible]	
.2500	[illegible]	.0065	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.0550	[illegible]	-.0590	[illegible]	[illegible]	[illegible]	O
.5000		[illegible]	[illegible]	-.0216	[illegible]	[illegible]	-.0609	-.0619	[illegible]	-.0659	-.0645	[illegible]	P
.6500			.0059	.0091	-.0163	[illegible]	[illegible]	-.0426	[illegible]	[illegible]	[illegible]		
[illegible]				[illegible]	.0252	-.0065	-.0193	[illegible]	-.0259	[illegible]			
.1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0268	.0190	.0150	[illegible]	[illegible]	
.2500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0255	.0157	.0019	.0052	[illegible]	[illegible]	B
[illegible]	.0570	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0177	[illegible]	[illegible]	[illegible]	[illegible]	T
.5000		.1271	[illegible]	[illegible]	.0694	.0629	[illegible]	[illegible]	.0121	.0016	[illegible]	-.0114	M
.6500			[illegible]	[illegible]	.1101	[illegible]	.0655	.0426	.0242	.0065	[illegible]		
[illegible]				[illegible]	.1104	[illegible]	.1059	[illegible]	[illegible]	.0154			
.1000	[illegible]	.0222	[illegible]	[illegible]	[illegible]	[illegible]	.0550	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	D
.2500	-.0013	[illegible]	[illegible]	[illegible]	.0714	.0557	.0642	.0550	.0419	[illegible]	[illegible]	[illegible]	I
[illegible]	.0222	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0760	[illegible]	[illegible]	[illegible]	[illegible]	F
.5000		[illegible]	.077	[illegible]	.1107	[illegible]	[illegible]	[illegible]	.0754	.0675	[illegible]	[illegible]	F
.6500			[illegible]	[illegible]	.1265	[illegible]	.1009	[illegible]	.0741	.0609	[illegible]		
[illegible]				[illegible]	[illegible]	[illegible]	.1252	.0767	[illegible]	[illegible]			

TABLE XVI (continued)

Warped Double Delta Wing Pressure Data

(c) Run 7 – With boundary layer trip (3) (cont'd)

$\alpha = 0$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0275	.0072	-.0006	-.0190	-.0196	[illegible]	-.0301	-.0334	-.0242	[illegible]	-.0406	[illegible]	
.2500	.0222	-.0111	-.0229	-.0498	-.0471	-.0255	-.0458	-.0452	-.0517	-.0426	[illegible]	-.0426	T
.4000	.0077	-.0262	-.0321	-.0714	-.0675	-.0694	-.0740	-.0731	-.0704	-.0605	-.0642	-.0657	O
.5000		-.0173	.0272	-.0662	-.0570	-.0661	-.0760	-.0790	-.0809	-.0803	-.0770	-.0741	P
.6500			-.0150	-.0134	-.0337	-.0449	-.0501	-.0554	-.0619	-.0659	-.0665		
.8000				-.0206	.0049	-.0219	-.0337	-.0370	-.0403	-.0422			
.1000	.0511	.0517	.0245	.0439	.0432	.0419	.0380	.0321	.0255	.0209	.0163	.0176	
.2500	.0471	.0530	.0557	.0425	.0471	.0412	.0327	.0229	.0075	.0111	.0271	.0150	B
.4000	.0452	.0471	.0447	.0426	.0419	.0415	.0412	[illegible]	.0155	.0101	.0062	.0011	T
.5000		.1619	.1664	.0655	.0950	.0799	.0583	.0422	.0259	.0140	.0036	-.0003	M
.6500			.0396	.2016	.1327	.1144	.0849	.0573	.0383	.0206	.0075		
.8000				.2462	.1268	.1006	.1537	.0685	.0475	.0291			
.1000	.0235	.0445	.0242	.0629	.0629	.0727	.0631	.0655	.0498	.0543	.0570	.0570	D
.2500	.0249	.0642	.0786	.1323	.0943	.0701	.0786	.0631	.0602	.0537	.0720	.0576	I
.4000	.0373	.0734	.0799	.1140	.1094	.1140	.1153	.1036	.0859	.0786	.0675	.0655	F
.5000		.1992	.1422	.1067	.1520	.1481	.1363	.1713	.1063	.0947	.0806	.0727	F
.6500			.0577	.2150	.1665	.1593	.1350	.1127	.1001	.0665	.0761		
.8000				.2669	.1239	.1226	.1875	.1055	.0878	.0714			

$\alpha = 1$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	.0157	-.0065	-.0117	-.0301	-.0281	-.0360	-.0347	-.0386	-.0301	-.0393	-.0455	-.0445	
.2500	-.0006	-.0301	-.0419	-.0734	-.0583	-.0301	-.0527	-.0517	-.0511	-.0493	-.0511	-.0493	T
.4000	-.0203	-.0557	-.0622	-.0871	-.0904	-.0930	-.0930	-.0875	-.0816	-.0744	-.0605	-.0632	O
.5000		-.0134	-.0032	-.0602	-.0747	[illegible]	-.0885	-.0921	-.0947	-.0960	-.0934	[illegible]	P
.6500			-.0390	-.0337	-.0508	-.0580	-.0626	-.0678	-.0737	-.0763	-.0770		
.8000				-.0196	-.0160	-.0377	-.0475	-.0501	-.0534	-.0554			
.1000	.0616	.0616	.0327	.0517	.0511	.0471	.0439	.0393	.0321	[illegible]	[illegible]	.0249	
.2500	.0557	.0609	.0642	.0910	.0550	.0475	.0606	.0301	.0157	[illegible]	.0196	.0216	B
.4000	.0255	.0543	.0547	.0491	.0492	.0550	.0547	.0422	.0265	.0213	.0147	.0200	T
.5000		.1926	.1979	.0736	.1154	.0969	.0740	.0573	.0401	.0272	.0167	.0134	M
.6500			.1072	.2154	.1513	.1341	.1013	.0737	.0547	[illegible]	.0206		
.8000				.2632	.1485	.1264	.1459	.0642	.0632	.0622			
.1000	.0654	.0681	.0645	[illegible]	.0793	[illegible]	.0776	.0779	.0627	.0661	.0661	.0695	D
.2500	.0563	.0910	.1061	.1645	.1173	.0779	[illegible]	.0819	.0666	.0631	.0707	.0716	I
.4000	.0657	.1101	.1160	.1362	.1602	[illegible]	.1156	.1294	.1072	.0957	.0862	[illegible]	F
.5000		.2261	.2012	.1579	.1900	.1808	.1625	.1695	.1350	.1232	.1101	.1071	F
.6500			.1662	.2491	.2026	.1921	.1619	.1416	.1285	.1101	.0977		
.8000				.3029	.1646	.1646	.1934	.1744	.1167	.0977			

$\alpha = 2$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0006	-.0222	-.0229	-.0612	-.0327	[illegible]	[illegible]	-.0426	[illegible]	[illegible]	-.0419	[illegible]	
.2500	-.0265	-.0550	-.0612	-.0729	-.0779	[illegible]	-.0645	-.0599	-.0594	-.0573	-.0573	[illegible]	T
.4000	-.0511	-.0736	-.0871	-.1062	-.1009	-.1009	-.0959	-.0924	-.0765	-.0826	-.0786	-.0747	O
.5000		-.0612	-.0253	-.0763	-.0667	-.0947	-.0999	-.1026	-.1019	-.1045	-.1013	-.0947	P
.6500			-.0570	-.0511	-.0649	-.0707	-.0741	-.0756	[illegible]	-.0759	-.0659		
.8000				-.0567	-.0350	-.0521	-.0606	-.0626	-.0645	-.0659			
.1000	.0707	.0727	.0491	.0596	.0570	.0557	.0517	.0471	.0393	.0353	.0263	.0321	
.2500	.0625	.0672	.0711	.1012	.0619	.0547	.0475	.0376	.0219	.0252	.0265	[illegible]	B
.4000	.0052	.0609	.0616	.0550	.0573	.0661	.0662	.0550	[illegible]	.0327	.0262	[illegible]	T
.5000		.2211	.2201	.0953	.1759	.1163	.0907	.0731	.0547	.0809	[illegible]	.0772	M
.6500			[illegible]	[illegible]	.1711	.1527	.1173	.0797	.0695	.0572	[illegible]		
.8000				[illegible]	.1727	.1459	.1662	.1006	.0777	.0560			
.1000	.0714	.0950	.0720	.1009	.0897	.0963	.0910	.0897	.0740	.0736	.0766	.0806	D
.2500	.0891	.1255	.1323	.1541	.1609	.0910	.1120	.0976	.0812	.0825	.0838	[illegible]	I
.4000	.0563	.1395	.1487	.1592	.1592	.1671	.1658	.1475	.1252	.1154	.1069	.1062	F
.5000		.2424	.2690	.1697	.2228	.2090	.1907	.1757	.1586	.1455	.1298	.1217	F
.6500			[illegible]	.2905	.2460	.2246	.1914	.1665	.1534	.1331	.1193		
.8000				[illegible]	.2078	.1950	.2270	.1632	[illegible]	.1219			

TABLE XVI (concluded)

Warped Double Delta Wing Pressure Data

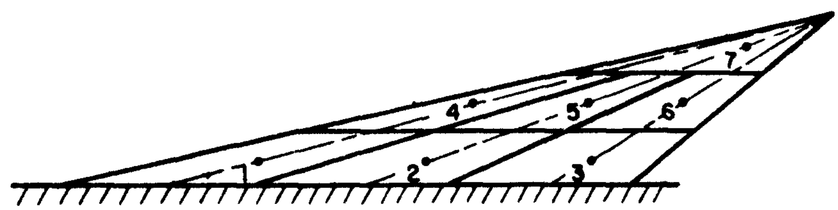
(c) Run 7 – With boundary layer trip (3) (concl'd)

$\alpha = 5$

y/b \ x/c	.0100	.0250	.0500	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000	
.1000	-.0494	-.0599	-.0593	-.0652	-.0855	-.0534	-.0481	-.0534	-.0527	-.0560	-.0606	-.0593	
.2500	-.0802	-.1032	-.0960	-.0953	-.0979	-.0462	-.1071	-.1091	-.1182	-.1110	-.0907	-.0704	T
.4000	-.1130	-.1097	-.1071	-.1071	-.1091	-.1110	-.1104	-.1085	-.1072	-.1078	-.1085	-.1075	O
.5000		-.0868	-.0802	-.1045	-.1130	-.1124	-.1130	-.1111	-.1091	-.1072	-.1059	-.1039	P
.6500			-.0993	-.0908	-.0973	-.0993	-.1013	-.1039	-.1059	-.1072	-.1078		
.8000				-.0967	-.0836	-.0901	-.0927	-.0934	-.0934	-.0941			
.1000	.0914	.0986	.0737	.0914	.0848	.0822	.0822	.0737	.0658	.0599	.0521	.0553	
.2500	.0711	.0822	.0901	.1353	.0848	.0796	.0750	.0645	.0468	.0501	.0488	.0534	B
.4000	-.0501	.0763	.0809	.0737	.0815	.0947	.1032	.0934	.0750	.0691	.0600	.0665	T
.5000		.2900	.2788	.1772	.1903	.1674	.1392	.1196	.1000	.0836	.0724	.0672	M
.6500			.1695	.3105	.2206	.2055	.1701	.1393	.1170	.0695	.0704		
.8000				.3269	.2613	.1937	.2154	.1459	.1209	.0986			
.1000	.1409	.1586	.1330	.1566	.1704	.1356	.1304	.1271	.1186	.1160	.1127	.1146	D
.2500	.1513	.1854	.1861	.2306	.1828	.1258	.1821	.1736	.1651	.1612	.1395	.1238	I
.4000	.0629	.1861	.1880	.1808	.1907	.2057	.2136	.2019	.1823	.1770	.1685	.1744	F
.5000		.3768	.3591	.2818	.3034	.2798	.2523	.2308	.2091	.1908	.1783	.1711	F
.6500			.2688	.4013	.3180	.3049	.2714	.2432	.2229	.1967	.1783		
.8000				.4236	.3449	.2839	.3082	.2393	.2144	.1920			

TABLE XVII

Flat Arrow Wing Structural Matrix and Deflection at $\alpha = 9°$.



Structural Matrix (deg./lb.)

Defl. Sta. \ Load Sta.	1	2	3	4	5	6	7
1	+0.009	+0.002	−0.002	+0.001	−0.004	−0.005	−0.008
2	+0.009	+0.004	−0.003	0.000	−0.003	−0.004	−0.008
3	+0.008	+0.002	−0.003	0.000	−0.003	−0.005	−0.010
4	+0.009	+0.004	−0.001	+0.002	0.000	−0.003	−0.008
5	+0.006	+0.001	−0.001	+0.002	−0.004	−0.001	−0.011
6	+0.006	+0.002	−0.001	+0.001	−0.001	−0.010	−0.023
7	+0.008	+0.004	−0.002	+0.002	−0.004	−0.011	−0.085

Co-ordinates of Stations

x/c	0.167	0.500	0.833	0.167	0.500	0.833	0.500
y/b	0.167	0.167	0.167	0.500	0.500	0.500	0.833

Area of Stations (in.^{2})

11.67	11.67	11.67	7.00	7.00	7.00	7.00

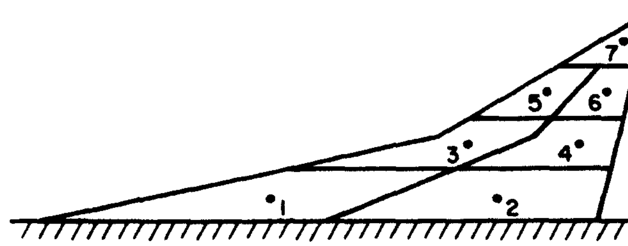
Total Area = 63 in.^{2}

Calculated Deflections (using Data from Run 6 $\alpha = 9°$) (degs.)

+0.02	+0.02	−0.04	+0.06	−0.07	−0.16	−0.56

TABLE XVIII

Flat Double Delta Wing Structural Matrix and Deflection at $\alpha = 9°$.



Structural Matrix (deg./lb.)

Defl. Sta. \ Load Sta.	1	2	3	4	5	6	7
1	0.0065	0.0000	−0.0005	−0.0040	−0.0035	−0.0050	−0.0080
2	0.0050	−0.0010	0.0000	−0.0025	−0.0030	−0.0045	−0.0050
3	0.0070	0.0000	0.0000	−0.0045	−0.0045	−0.0065	−0.0080
4	0.0045	−0.0010	0.0000	−0.0075	−0.0085	−0.0165	−0.0250
5	0.0055	0.0000	−0.0010	−0.0075	−0.0130	−0.0290	−0.0520
6	0.0055	−0.0015	0.0000	−0.0075	−0.0105	−0.0385	−0.0770
7	0.0060	−0.0005	−0.0010	−0.0090	−0.0110	−0.0435	−0.2110

Co-ordinates of Stations

x/c	0.25	0.75	0.25	0.75	0.25	0.75	0.50
y/b	0.125	0.125	0.375	0.375	0.625	0.625	0.875

Area of Stations (in.^{2})

15.8	15.8	7.65	7.65	3.68	3.68	2.45

Total Area = 56.7 in.^{2}

Calculated Deflections (using Data from Run 18 $\alpha = 9°$) (degs.)

−0.03	−0.01	−0.02	−0.20	−0.35	−0.35	−0.98

APPENDIX I

GRANT'S PRESSURE COEFFICIENT SERIES

F.C. Grant (Ref. 18) applied Lagrange's method of undetermined multipliers to the problem of properly combining lift loadings for minimum drag at fixed lift. He considered a superposition of N loadings such that

$$\Delta C_p \equiv \frac{\ell(x,y)}{q} = a_1 P_1(x,y) + a_2 P_2(x,y) + \ldots + a_N P_N(x,y) \qquad (25)$$

where the a_i are strength parameters and the P_i are elementary loadings ($P_i \equiv \ell_i/q$). ΔC_p is the resultant lifting pressure coefficient at a point on the planform. According to linear theory, the corresponding local angle of attack may be written as

$$\alpha(x,y) = a_1 \alpha_1(x,y) + a_2 \alpha_2(x,y) + \ldots + a_N \alpha_N(x,y) \qquad (26)$$

where α_i is the angle of attack distribution which corresponds to the loading P_i. Excluding thrust-loaded singularities from the drag (for convenience and because leading-edge thrust has not been realized experimentally, anyway), a formula for the drag coefficient is

$$C_D = \frac{1}{S} \int \Delta C_p \cdot \alpha \, dS = \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} C_{D_{ij}} a_i a_j \qquad (27a)$$

where

$$C_{D_{ij}} = C_{D_{ji}} = \frac{1}{S} \int (P_i \alpha_j + P_j \alpha_i) \, dS \qquad (27b)$$

The lift coefficient is

$$C_L = \frac{1}{S} \int \Delta C_p \, dS = \sum_{i=1}^{N} C_{L_i} a_i \qquad (28a)$$

where C_{L_i} is the lift coefficient due to the loading P_i:

$$C_{L_i} = \frac{1}{S} \int P_i \, dS \tag{28b}$$

C_D being quadratic in the a_i's and C_L linear, Lagrange's method of undetermined multipliers is useful to obtain a set of linear algebraic equations which may be solved for the unknown a_i's. Forming the function

$$F = C_D + \lambda C_L$$

where λ is the Lagrange multiplier, the minimum value of F as determined by the N linear algebraic equations $\partial F/\partial a_i = 0$ plus condition (28a) is Lagrange's solution. In matrix form these equations are

$$\begin{bmatrix} 2C_{D_1} & C_{D_{12}} & C_{D_{13}} & \cdots & C_{D_{1N}} & C_{L_1} \\ C_{D_{12}} & 2C_{D_2} & C_{D_{23}} & \cdots & C_{D_{2N}} & C_{L_2} \\ C_{D_{13}} & C_{D_{23}} & 2C_{D_3} & \cdots & C_{D_{3N}} & C_{L_3} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ C_{D_{1N}} & C_{D_{2N}} & C_{D_{3N}} & \cdots & 2C_{D_N} & C_{L_N} \\ C_{L_1} & C_{L_2} & C_{L_3} & \cdots & C_{L_N} & 0 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_N \\ \lambda \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ C_L \end{bmatrix} \tag{29}$$

After solving the matrix equation, the a_i's may be substituted back in Eq. (AI.1) to obtain the "optimum" load distribution (i.e., the optimum combination of the N assumed elementary loadings) and in Eq. (27.a) to obtain the corresponding minimum drag. Alternately, the minimum drag is more simply found from the Lagrange multiplier λ through the relation, derived by Grant,

$$C_{D_{min}} = -\frac{1}{2} \lambda C_L \tag{30}$$

In his examples, Grant uses the four-term polynomial loading series

$$\Delta C_p = a_1 + a_2 \frac{x}{l_0} + a_3 \frac{|y|}{b} + a_4 \frac{y^2}{b^2} \tag{31}$$

(The notation is indicated in Fig. 1.) This approximation has at least two important advantages:

1. Formulas for the surface coordinates of delta and arrow wings which support each of the four elementary pressure distributions were available from previous work due to Tucker (Ref. 27). The formulas apply for subsonic leading-edges and supersonic trailing edges.

2. The first term of the series, $P_1 = 1$, represents a constant pressure over the planform. Because of the absence of pressure gradient this might be expected to be a useful loading for lessening the separation problems. In addition it yields, by itself, a significantly smaller drag-due-to-lift than does the flat-plate loading for the same planform (if leading-edge suction is omitted). The other terms in Eq. (31) introduce pressure gradients, of course, but at the same time effect reduction in the theoretical drag coefficient. In some cases, the required pressure gradients may be sufficiently small so as not to induce separation. In other cases, it may be necessary for the designer to compromise at some stage between additional predicted drag reduction and permissible pressure gradients.

APPENDIX II

COMPUTATION PROCEDURE

By Roy Krupp

Section I The Equations

We are interested in computing angle of attack and "interference drag" terms in order to optimize drag coefficients according to the linear theory. These are defined:

$$\overline{\alpha}\,(x, y) = \lim_{z \to 0} \iint K\,(z, u, v,)\;\overline{P}\,(\overline{x}, \overline{y})\,d\overline{x}\;d\overline{y}$$

$$D = \iint (P\overline{\alpha} + \overline{P}\alpha)\;dx\;dy,$$

where $u = \overline{x} - x$

$v = \overline{y} - y$

$\overline{x}$ and $\overline{y}$ are dummy variables

The integrals are over wing planform, P and $\overline{P}$ are arbitrary load distributions, and the kernal K is singular at z = 0, so that we cannot simply exchange the order of limiting and integration processes. Instead, we have the formula (Ref. 55).

$$\lim \iint K P = \frac{\beta}{4} P(x, y) + \frac{1}{4\pi} \oint \frac{RP}{uv}\,d\overline{x} + \frac{1}{4\pi} \iint \frac{RP_y}{uv}\,d\overline{x}\;d\overline{y}$$

$$R = \sqrt{u^2 - \beta^2 v^2}\quad .$$

where the double integral is over the forward Mach cone at (x, y), the contour integral is along both sides of each discontinuity of P (in particular the leading edge of the planform) in the forecone, and the Cauchy integral is intended wherever the integrand is singular. If we assume P continuous (except at the leading edge):

$$\alpha = \frac{\beta}{4} P(x, y) + \frac{1}{4\pi} \int_{-\pi/2}^{\pi/2} \frac{\cos^2\theta}{\sin\theta} \left\{ \frac{P(\overline{x}, \overline{y})}{m - \frac{1}{\beta}\sin\theta} + \int P_{\overline{y}}\,(\overline{x}, \overline{y})\,d\overline{x} \right\} d\theta$$

$$\sin\theta = \beta v / u$$

where m is the slope of the leading edge. Clearly, the Cauchy integral is finite unless P/m or $\int P_{\bar{y}}\, d\bar{x}$ is discontinuous at $\theta = 0$ (that is, at $\bar{y} = y$), or unless P or m is discontinuous at $m\beta = \sin\theta$. The first case occurs along a line behind a break in the slope of the leading edge unless $P = 0$ or $P_1/m_1 = P_2/m_2$, where 1 and 2 denote limiting values at each side of the break. The second case occurs, for example, at $y = 0$ for $P = |y|$. The third case occurs along a subsonic leading edge unless $P = 0$ there.

While α may be infinite, drag is nevertheless finite and can be written in such a way that no intermediate infinities are encountered. We observe that the integral defining D is absolutely convergent and write:

$$D = \lim \iint K \iint \left[P(x, y)\, \overline{P}(x+u, y+v) + \overline{P}(x, y)\, P(x+u, y+v) \right] dx\, dy\, du\, dv$$

$$= \lim_{z \to 0} \iint K(z, u, v)\, \tilde{P}(u, v)\, du\, dv$$

where we have interpreted a correlation integral of P and $\overline{P}$ as a new loading $\tilde{P}(u, v)$ associated with a new wing planform. The integral defining $\tilde{P}$ is carried out over the region of overlap of the original planform with the figure (See Fig. AII-1) which results from displacing it by the vector (u, v). Thus the drag is formally equivalent to the angle of attack at $(0, 0)$ of the new wing. Further, if P and $\overline{P}$ are bounded, then $\tilde{P}$ is continuous and goes to zero at all edges of the new wing planform. Thus, we may write:

$$D = \frac{\beta}{4} \tilde{P}(0, 0) + \frac{1}{4\pi} \int_{-\pi/2}^{\pi/2} \frac{\cos^2\theta}{\sin\theta} \int \tilde{P}_v(u, v)\, du\, d\theta$$

The planform of the new wing (See Fig. AII-2) in u, v - space is the set of all vectors (u, v) which may be placed on the original planform so that both endpoints lie on the wing (the line joining these points may pass outside the wing). If $\tilde{P}$ is an even function of v (which is the case if P and $\overline{P}$ are even and the original planform is symmetric), then the pole at $\theta = 0$ is cancelled by a zero. Otherwise the Cauchy integral may be

needed. A more direct approach, on the other hand, calculating first the angles of attack and then the drag, requires the integration of logarithmic infinities, which possess no useful symmetries.

The secret of evaluating a Cauchy integral (e.g., to compute angle of attack) numerically lies in arranging for the singularity to appear in the antisymmetric part of an integrand over some interval which is symmetric with respect to the location of the singularity. For example:

$$\int_a^b f \frac{dx}{x} = \int_a^{-b} f \frac{dx}{x} + \int_{-b}^{b} f \frac{dx}{x}, \quad a < -b$$

Now using, say, a Gaussian quadrature formula on an even number of points and breaking up the integrand $f = f_e(x^2) + x f_0(x^2)$ we get:

$$\int_{-b}^{b} f \frac{dx}{x} \cong \sum w_k \left(f(x_k) - f(-x_k)\right)/x_k = 2 \sum w_k f_0(x_k^2)$$

which is manifestly finite. Since we may be dealing with the differences of large quantities, it is preferable to use a double-precision arithmetic.

The computation of various double integrals is most readily mechanized by having a subroutine list out the vertices in order (counter-clockwise, say) and feed them, three at a time, to another routine which performs quadratures over a triangle. Section II describes a procedure of ninth order for performing the quadrature. It is slightly more efficient than the iterated Guassian formula, and possesses the correct symmetries under the permutation group on the triangle.

Section II Triangle Integration Formula

When f(x, y) is a polynomial of order 9 or less the following formula is exact:

$$\frac{1}{s}\iint_{\Delta} f\,dx\,dy = \sum_{n=1}^{6} W_n \sum_{\alpha,\beta,\gamma} f(x_n, y_n),$$

where

$$x_n = \alpha_n a_1 + \beta_n b_1 + \gamma_n c_1,$$

$$y_n = \alpha_n a_2 + \beta_n b_2 + \gamma_n c_2,$$

s = area of triangle,

(a_1, a_2), (b_1, b_2), (c_1, c_2) are vertices.

The second sum on the right is over the six permutations of (α, β, γ). The quantities $(\alpha_n, \beta_n, \gamma_n, W_n)$ are tabulated below. (α, β, γ) are barycentric coordinates of points inside the triangle since:

$$\alpha > 0,\ \beta > 0,\ \gamma > 0,\ \alpha + \beta + \gamma = 1$$

Note that certain of the permutations do not represent distinct points, so that f must be evaluated 19 times altogether.

.333333333333	.333333333333	.333333333333	.016189299380
.020634961604	.489682519198	.489682519198	.015667350113
.125820817014	.437089591493	.437089591493	.038913770502
.623592928762	.188203535619	.188203535619	.039823869463
.910540973211	.044729513394	.044729513394	.012788837829
.036838412054	.221962989160	.741198598784	.043283539377

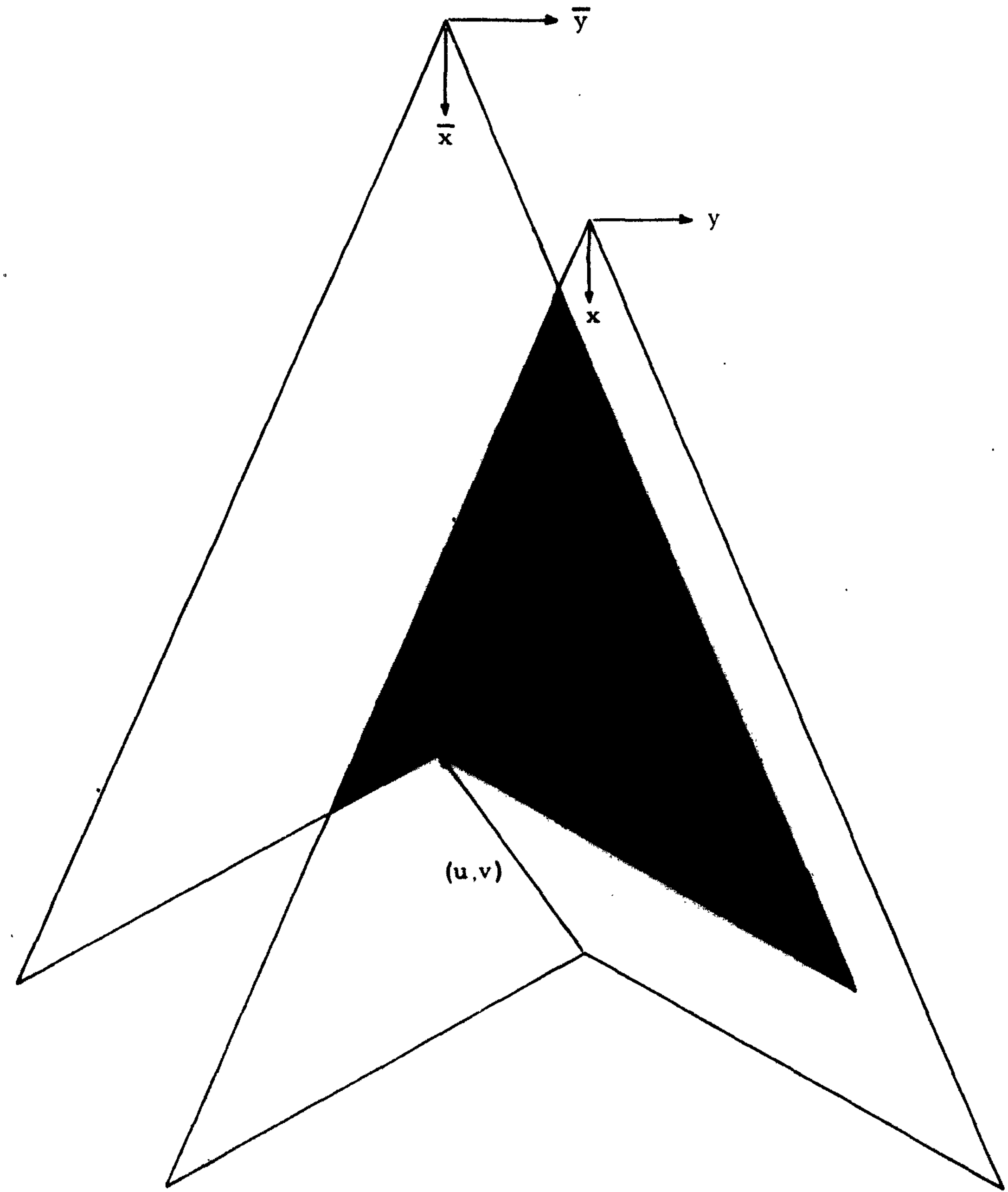


Figure 47. Typical overlap region for correlation integral

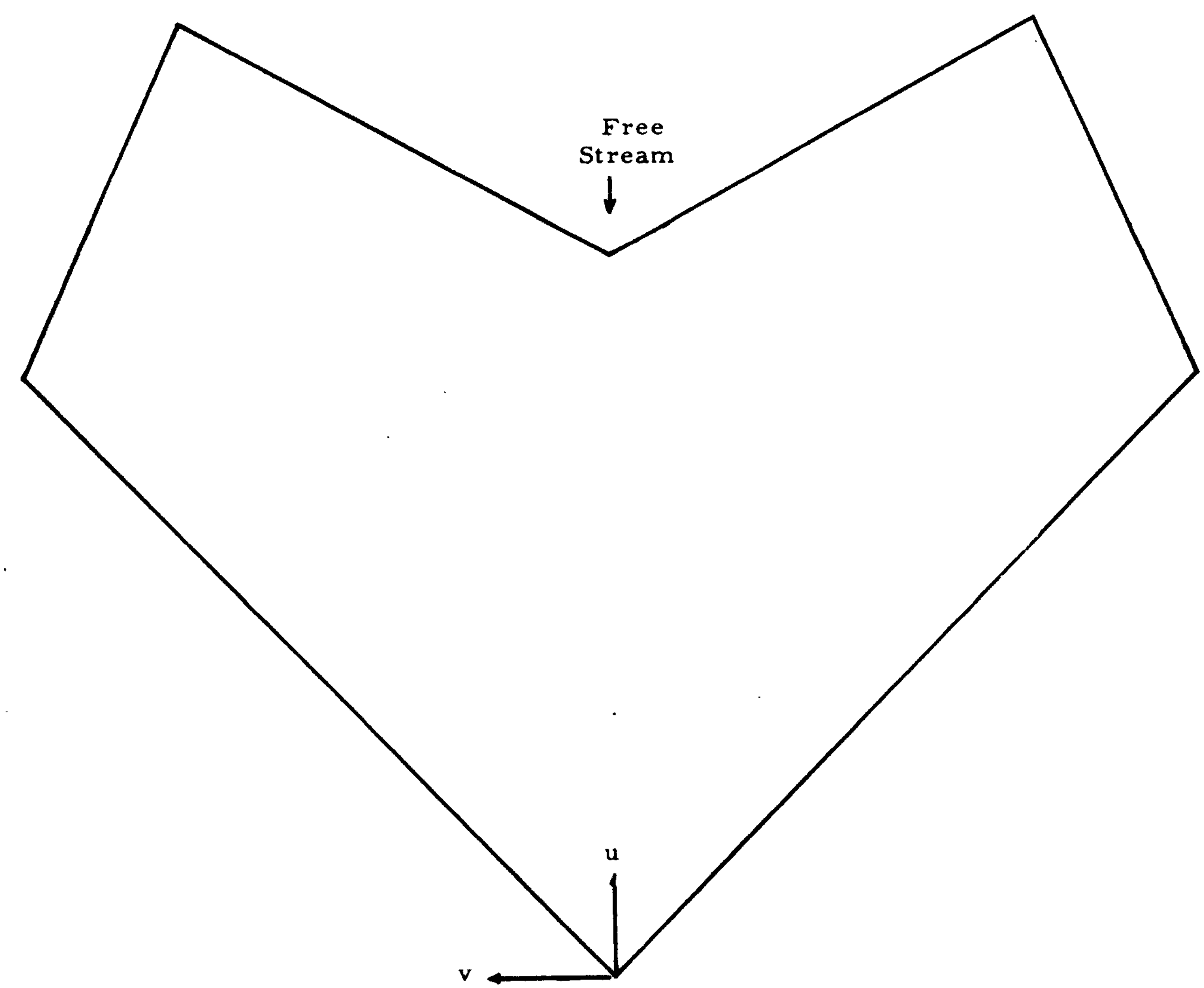


Figure 48. Portion of "New Wing" lying in forecone of (0, 0) in u, v-plane for a typical arrow wing

Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, Rpt No. FDL-TDR-64-109, MIT TR 95, A STUDY OF TWIST AND CAMBER ON WINGS IN SUPERSONIC FLOW by Frank H. Durgin. Final Report, November 1964, xv and 176 p. incl. illus., tables, 55 refs.

Unclassified Report

The object of this program was to study both theoretically and experimentally methods for designing the twist and camber of wing planforms to yield high lift-drag ratios at supersonic speeds. Calculations based on linear supersonic wing theory were made to determine the effects of various types of lead distributions on the drag due to lift and on the wing shape. In particular, only solutions with smooth finite pressure distributions and finite perturbation velocities, leading to easily built wing shapes, were accepted. It was hoped, by imposing such constraints, to avoid the high drag losses due to shock waves, flow separation and the formation of detached vortices.

The calculation procedure was used to design versions of arrow and double delta planforms warped to obtain improved drag due to lift at Mach number 3. Both flat and warped versions of each planform were tested and both force and pressure data were obtained on all the wings.

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2. Supersonic flow
3. Wing optimization

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This technical documentary report has been reviewed and is approved.

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